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THE GEOLOGY

OF

NEW HAMPSHIRE.

A REPORT COMPRISING THE RESULTS OF EXPLORATIONS ORDERED BY THE LEGISLATURE.

C. H. HITCHCOCK,
STATE GEOLOGIST.

J. H. HUNTINGTON,
PRINCIPAL ASSISTANT.

PART I. PHYSICAL GEOGRAPHY.

CONCORD:
EDWARD A. JENKS, STATE PRINTER.
1874.

PREFACE.

It has been found impossible to treat of the subjects of metamorphism, elevation of mountains, and earthquakes within the limits of this volume, as originally contemplated, but we hope not to neglect them altogether, as provision has been made for the printing of another book, devoted more particularly to geology and mineralogy, in which these topics will be fully discussed.

Some of the following chapters have been prepared by gentlemen eminent in their several specialties, not officially connected with the Survey, who have kindly devoted their time and strength to the work without remuneration for their services. To them our thanks are specially extended.

Mr. Warren Upham, of Nashua, compiled the interesting chapter upon the History of Explorations among the White Mountains, and the description of the river systems. If the observations upon altitudes constitute the most thorough and perhaps most useful chapter in the volume, it is due to the indefatigable diligence of Mr. Upham, in comparing the various railroad surveys from different parts of the state, sifting out what seemed unreliable, and matching them together into one connected whole.

With such substantial foundations established for the elucidation of the water-power of the state as are afforded by these two chapters, it is to be hoped that the Executive will call to mind an act passed by the legislature in reference to the appointment of a hydrographic commission. The information in this report would be of so much service to that commission, that the sum appropriated for their work would be sufficient to bring out results of great benefit to the state, which could not otherwise have been obtained to so good advantage.

The valuable treatises of Mr. S. H. Scudder, of Cambridge, Mass., upon the Distribution of Insects, of Dr. A. M. Edwards, of Newark, N. J., upon the Natural History of the Diatomaceæ, and of Mr. W. F. Flint, of Richmond, upon the Distribution of Plants, are well adapted to awaken among our citizens a new interest in the departments of entomology, microscopy, and botany. Should this result follow, the several gentlemen will feel themselves amply repaid for their exertions in our behalf.

Prof. Quimby's essay upon the use of the magnetic needle in surveying has been issued separately, for the benefit of students and engineers.

Mr. Isaac N. Andrews, of Nashua, has rendered the appearance of the volume more satisfactory by allowing us the privilege of copying many of the elegant wood-engravings, relating to White Mountain scenery, from the *White Hills*, by the late Rev. T. Starr King.

The Atlas will show very important contributions to the study of our topography, in the truthful delineations of outline sketches, from prominent points, of the White Mountains, prepared by the skilful hand of Mr. Geo. F. Morse, of Portland, Me., who has devoted much time to their preparation.

It was found impossible to obtain a satisfactory heliotype of the view of the White Mountain range from Jackson, which was intended for the frontispiece. In its place we have inserted the view illustrating the ledges fractured by frost, upon the summit of Mt. Washington. For a similar reason, the view of the White Mountain Notch from Mt. Willard, accompanying one of the Willey house, is copied from a hand sketch.

C. H. HITCHCOCK.

HANOVER, Dec. 1, 1874.

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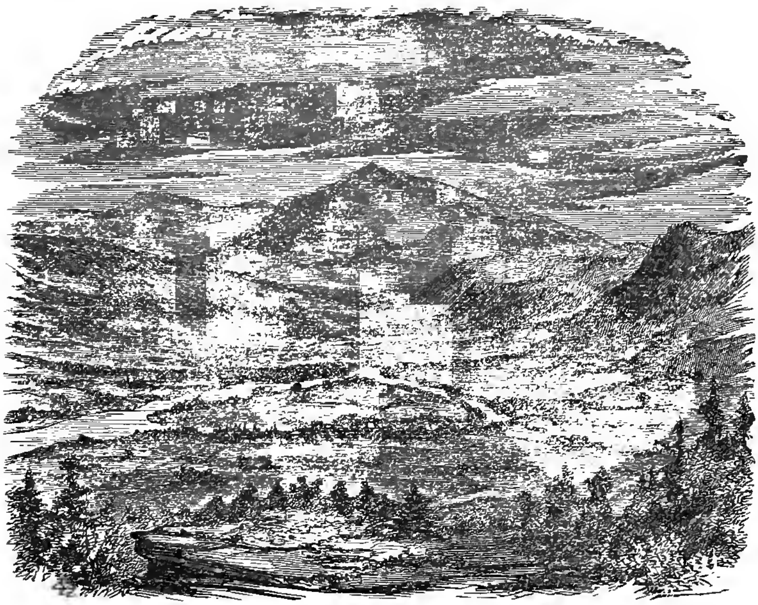
PART I.

PHYSICAL GEOGRAPHY.



MTS. MADISON AND WASHINGTON FROM SHELBURNE.

CHAPTER I.

HISTORY OF GEOLOGICAL SURVEYS IN NEW HAMPSHIRE.

THE first public notice of the importance of examining the mineral resources of New Hampshire which I can find is contained in a message of His Excellency Levi Woodbury, governor, to the legislature, in June, 1823. He recommended the institution of an agricultural survey, with a view to the chemical analysis of the various kinds of soils. In support of this proposal he quoted the following passage from the constitution of the state: "It shall be the duty of legislators and magistrates, at all future periods of this government, to cherish the interests of literature and the sciences." It also inculcates "the promotion of agriculture, the arts, sciences, commerce, trades, manufactures, and the natural history of the country." Had this recommendation been adopted, New Hampshire would have been the first of the United States to inaugurate a scientific survey of its mineral resources.

About 1837 or 1838, His Excellency Isaac Hill, governor, urged the propriety of authorizing a geological and mineralogical survey, with a view to the advancement of agriculture and the arts. This was the epoch when most of the states had either inaugurated or were considering the propriety of establishing geological surveys. Massachusetts had recently so successfully completed a triennial survey of her territory, under the superintendence of my honored father, the late Professor Edward Hitchcock, that the utility of such explorations was well appreciated. In 1839, His Excellency John Page, governor, advocated a survey of New Hampshire with such success that the legislature passed the following act in reference to it:

AN ACT to provide for the geological and mineralogical survey of the state.

SECTION 1. *Be it enacted by the Senate and House of Representatives in General Court convened,* That the governor of this state is hereby authorized and required, as soon as may be after the passage of this act, to appoint a state geologist, who shall be a person of competent scientific and practical knowledge of the sciences of geology and mineralogy; and the said state geologist shall, by and with the consent of the governor and council, appoint one suitable person to assist him in the discharge of his duties, who shall be a skilful analytical and experimental chemist.

SEC. 2. *And be it further enacted,* That it shall be the duty of the said state geologist and his said assistant, as soon as may be practicable after their appointment, to commence and carry on, with as much expedition and dispatch as may be consistent with minuteness and accuracy, a thorough geological and mineralogical survey of this state, with a view to determine the order, succession, arrangement, relative position, dip or inclination, and comparative magnitude of the several strata or geological formations within this state, and to discover and examine all beds or deposits of ore, coal, clay, marls, and such other mineral substances as may be useful or valuable, and to perform such other duties as may be necessary to make a full and complete geological and mineralogical survey of the state.

SEC. 3. *And be it further enacted,* That it shall be the duty of the said assistant to make full and complete examinations, assays, and analyses of all such rocks, ores, soils, or other substances as may be submitted to him by the state geologist for that purpose, and to furnish him with a detailed and complete account of the results so obtained.

SEC. 4. *And be it further enacted,* That it shall be the duty of the said state geologist, on or before the first day of June in each and every year during the time necessarily occupied by said survey, to make an annual report of the progress of said survey, accompanied with such maps, drawings, and specimens as may be necessary and proper

to exemplify and elucidate the same, to the secretary of state, who shall lay such report before the legislature.

SEC. 5. *And be it further enacted*, That it shall be the duty of the said state geologist to cause to be represented on the map of the state, by colors and other appropriate means, the various areas occupied by the different geological formations in the state, and to mark thereon the localities of the respective beds or deposits of the various mineral substances discovered; and, on the completion of the survey, to compile a memoir of the geology and mineralogy of the state, comprising a complete account of the leading subjects and discoveries which have been embraced in the survey.

SEC. 6. *And be it further enacted*, That it shall also be the duty of the said state geologist to forward to the secretary of state, from time to time during the progress of such survey, such specimens of the rocks, ores, coals, soils, fossils, and other mineral substances discovered and examined, as may be proper and necessary to form a complete cabinet collection of specimens of geology and mineralogy of the state; and the said secretary shall cause the same to be deposited in proper order in some convenient room in the state capitol, there to be preserved for public inspection.

SEC. 7. *And be it further enacted*, That for the purpose of carrying into effect the provisions of this act, the sum of two thousand dollars is hereby annually appropriated for the term of three years, to be expended under the direction of the governor: *provided, however*, that the salaries of the said state geologist and his assistant shall not commence until they have entered upon the execution of their duties, and, upon the completion of said survey and of the duties connected therewith, they shall wholly cease and determine.

MOSES NORRIS, JR.,
Speaker of the House of Representatives.

JAMES McK. WILKINS,
President of the Senate.

Approved June 24, 1839.
JOHN PAGE,
Governor.

In accordance with the provisions of this act, Dr. Charles T. Jackson, of Boston, was appointed State Geologist September 10, 1839, and entered upon the duties of the office June 1, 1840. He devoted the principal part of three years to his researches. It was understood and agreed between the parties that the surveyor should devote four months to the researches required in the field, and that four months should be spent in the analysis of the minerals obtained; but, as the laboratory work proved more difficult and extensive than was at first apprehended, nearly the whole remaining four months of the year were occupied in the

requisite examinations. Additional appropriations were made in subsequent years, so that the total cost of the first survey amounted to $9,000, independently of the expense of publication.

Dr. Jackson employed assistants, whose names and time of service appear to have been as follows: J. D. Whitney, appointed December 7, 1840, and served during that winter; M. B. Williams, appointed June, 1841, and served during the summer of that year; W. F. Channing, appointed June 7, 1842, and served during the summer of that year Eben Baker served in the autumn and winter of 1842; John Chandler served in the winter of 1842. Their services are said to have been gratuitous, the survey paying only the necessary travelling expenses. Some of these gentlemen performed field work other than has been specified,—which service will be noted presently.

Four volumes and pamphlets appear to have been published, containing an account of these researches, as follows:

First Annual Report on the Geology of the State of New Hampshire. By Charles T. Jackson, State Geologist. 8vo, 164 pp. Concord: Barton & Carroll, State Printers, 1841.

Second Annual Report on the Geology of the State of New Hampshire. By Charles T. Jackson, State Geologist. 8vo, 8 pp. 1842. Concord: State Printers.

Final Report on the Geology and Mineralogy of the State of New Hampshire, with Contributions towards the Improvement of Agriculture and Metallurgy. By C. T. Jackson, M. D. 4to, 384 pp., 11 plates. Concord, 1844. Carroll & Baker, State Printers.

I find, also, in various quarters, reference to another volume published in the following year, probably at the author's expense.

Views and Maps of Final Report. Reprinted. 4to, 20 pp., 8 plates. Boston, 1845.

The Final Report is made up of the following parts:

Reprint of two Annual, with the Third Annual Report, . . .	136 pages.
Preliminary Remarks on the General Science of Geology, . . .	28 pages.
Laws and Official Documents Relative to Survey, ...	8 pages.
Economical Geology, ...	72 pages.

Agricultural Geology and Chemistry, ...	39 pages.
Appendix to Geology, ...	4 pages.
Barometrical Tables, ...	35 pages.
Appendix to Agricultural Geology and Chemistry, ...	45 pages.
Glossary, Index, and Errata, ...	11 pages.

In the first annual report is described the method of proceeding with the explorations. Knowing that the strata pursue a general north-east course, Dr. Jackson proposed to cross them several times at right angles, and also along their line of strike, or a north-east course. These lines of explorations would divide the territory into triangular areas whose boundaries would be known, and various excursions across them would make the knowledge of each tract more or less accurate. The cross sections described are from Portsmouth to Claremont through Concord; from Concord to Wakefield; from Wakefield to Haverhill,—all measured by Messrs. Whitney and Williams. Dr. Jackson measured another, from Concord to Winchester, traversing outside of the line the towns of Amherst, Peterborough, Dublin, Keene, and Brattleborough. Messrs. Whitney and Williams also travelled to the northern corner of the state as far as Mt. Carmel; and this section is connected with a longitudinal section along Connecticut river, measured by Dr. Jackson from Haverhill to Northfield, Mass. The field work closed after a tour to the White Mountains, including Jackson, Eaton, and Mt. Gunstock.

The pamphlet report of the first year's work contains remarks upon economical geology and agriculture, but does not exhibit any illustrations of the sections. Those were reserved for the quarto volume, and consist of the ones enumerated as measured by Whitney and Williams, and the longitudinal one along Connecticut river as far as Mt. Carmel (Camel's Rump). The former are much superior in artistic execution to the latter. Excepting one theoretical section and the geological map, the material for the plates seems to have been entirely obtained from the results of this year's explorations.

Second Year's Work. The second year's explorations commenced at Nashua. A party of assistants explored the southern range of towns between Nashua and Connecticut river; but they do not seem to have

furnished any facts for the text. Dr. Jackson himself took the opposite direction, exploring between Nashua and Portsmouth. From thence he travelled to Madison (then a part of Eaton), Mt. Chocorua (Williams and Channing), Jackson, Randolph, Lancaster, Shelburne, back to Lancaster and Dixville notch. Next he measured a section through Vermont, from Lancaster to Lake Champlain. The facts derived from this line of survey, as well as on a return line farther south, are generalized in a section, the substance of which I have reproduced in Fig. 1. Meanwhile, Messrs. Channing and E. E. Hale examined the northern frontier, or the Canadian borders of New Hampshire and Vermont. The rest of the year's field-work consisted of explorations in Littleton, Franconia, Landaff, Orford, Lyme, Canaan, Grafton, Amherst, and a hasty trip from Amherst to Keene.

Third Year's Work. The third report states that the towns which had not been previously visited were examined as far as practicable. Those mentioned are Epsom, Pittsfield, Barnstead, Strafford, Temple, Richmond, Winchester, Hinsdale, Guilford, Vt., Warren, Springfield, Enfield, Canaan, Gilmanton, Sandwich, Jackson, Mt. Crawford, Dalton, Warren, down Connecticut river to Charlestown, Unity, and an excursion to Mt. Washington from Jefferson, by Messrs. Channing and Hale. This year's report closes with a fuller sketch of the previous year's work of measuring sections across Vermont.

Building Materials, Metallurgy, etc.

The economical part of the report describes granite, soapstone, slate, quartz, limestone, scythe-stones, beryl, garnet, infusorial silica, ochres for paints, plumbago, pyrites, and some other minerals. It is quite full in metallurgical statements respecting iron, zinc, copper, lead, tin, silver, gold, molybdenum, manganese, and arsenic. Many original chemical analyses are given in connection with these economical and metallurgical descriptions.

The agricultural portion is divided into five parts: 1. The origin and distribution of soils. 2. Nature and origin of the organic and saline ingredients of soils. 3. Chemical constitution of plants. 4. What ingre-

dients are taken from the soil by crops. 5. Best methods of restoring fertility to exhausted soils, and of improving those that are infertile. It concludes with descriptions of the methods of conducting agricultural operations by several eminent gentlemen, as at the Derby farm on Cow island, Winnipiseogee lake; the Shaker farm, in Canterbury; Levi Bartlett's farm, in Warner; David Stiles's farm, in Lyndeborough; Judge Hayes's farm, in South Berwick, Maine, and others.

The barometrical observations are incomplete, and in a few cases the altitudes have been calculated from them. All that are of value I have had reduced, and given in a list of heights in a subsequent chapter.

The appendix to agricultural geology contains a large number of soil analyses, mostly original.

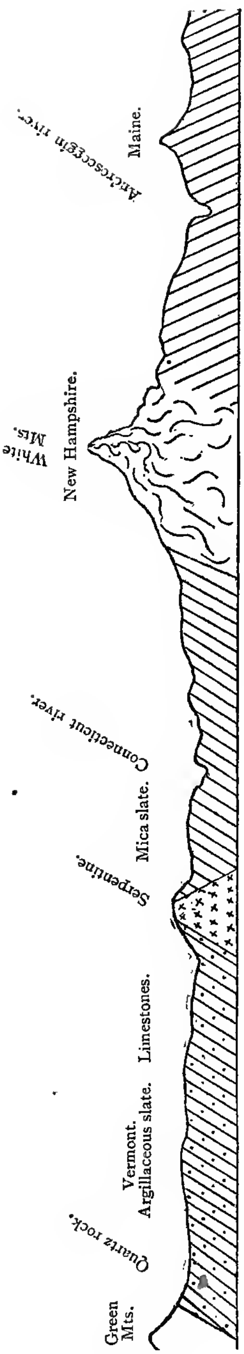
Geological Map.

The state authorities did not think it important to color the geological map attached to Jackson's report. Hence it has become difficult to understand many things which otherwise might have been evident. Carrigain's map seems to have been the topographical basis, with, no doubt, many corrections of town boundaries and various minute points, though the mountains are not reproduced. The scale is exactly half that of Carrigain's. The geological distinctions are the following: 1. Granite, sienite and gneiss. 2. Mica slate. 3. Hornblende rock. 4. Argillaceous slate. 5. Drift. 6. Alluvium. There are numerous symbols to denote the location of quartz rock, trap, limestone, talc and soapstone, peat, iron, lead, zinc, tin, copper, pyrites, silver, gold, titanium, titanic iron, plumbago, beryl, mica, manganese, arsenic, and molybdenum. Other symbols indicated the place where mines or quarries were worked, the dip and direction of strata, and anticlinal axes.

Jackson's Theory of Geological Structure.

These reports and map being chiefly descriptive of mineral localities, it is difficult to deduce from them a very satisfactory notion of stratigraphical structure. In general, he seems to have regarded the rocks of New Hampshire as "Primary," or the oldest to be met with between

Fig. 1.



DR. JACKSON'S IDEAL SECTION.

Nova Scotia and Pennsylvania. His ideal section represents the New Hampshire rocks as granite at the White Mountain centre, with gneiss upon both sides, dipping on the east towards Maine, and on the west towards Vermont. The schistose rocks adjacent to the gneiss in Maine and Vermont are called "Cambrian." The Green Mountains of Vermont are made out to be an immense stratum of quartz rock, dipping westerly. These Cambrian strata in their turn are flanked on their outer sides by Silurian, and these in their turn by Carboniferous rocks, in the extremes of Nova Scotia and Pennsylvania.

Not to be misunderstood, I have reproduced here Dr. Jackson's ideal section. I shall attempt hereafter to point out that in this idea there is an important element of truth, while many of the details are incorrect. It is true, for instance, that in the White Mountain neighborhood the older rocks make their appearance. This view is derived from the study of the formations in the field, and is at variance with the prevalent opinions of American geologists, as held in 1868, when our explorations commenced. The quotation given in Chapter II shows that our first explorations about Lisbon led to the conclusion

that the White Mountain series were older than those in the Ammonoosuc and Connecticut valleys. In the year following, 1870, Dr. T. Sterry Hunt published a letter suggesting whether he had not been at fault heretofore in calling the White Mountain rocks Paleozoic. In 1871 he proposed to call them pre-Cambrian.*

Dr. Jackson's section is wrong in such details as these. The granite does not constitute the central axis of the White Mountains; the strata are not regular in their dips upon both sides of the axis, there being overturns as well as repetitions of older formations. The Green Mountains are not made up in the mass, nor in any part, of quartz rock in the position indicated, and the term Cambrian is misapplied.

Territorially, Dr. Jackson's oldest division is made to occupy the principal part of the state. The most northern locality specified is at Berlin. It occupies the greater portion of the breadth of the state in the latitude of Bristol. South of this line there are only isolated granitic patches west of the Merrimack river, while a broad band of it extends nearly as far as Concord on the east side.

The mica slate formation occupies most of the territory south of the latitude of Franklin, passes up to Jackson on the east and to Columbia on the west side of the first and fundamental group. There is also a little represented as lying upon Mt. Washington.

The third division—"hornblende rock"—is very limited, appearing only in Hanover, Wakefield, and Acworth. The fourth—"clay slate"—appears along Connecticut river, in Hinsdale, Chesterfield, Dalton, and Lancaster; on the east side of Mt. Washington; along Salmon river, in Rochester, Somersworth, Newington, Portsmouth, and also Rye.

"Drift" is shown along the Merrimack river, in Hudson, Litchfield, Pembroke, Northfield, Holderness, and Woodstock. It seems to include some extensive sandy plains properly belonging to the next division. "Alluvium" appears in the same valley in Concord, and New Hampton, in the bend opposite Bristol village; also on the Connecticut, in Hinsdale, Westmoreland, Piermont, Haverhill, and Lancaster. The localities of minerals and ores need not be enumerated.

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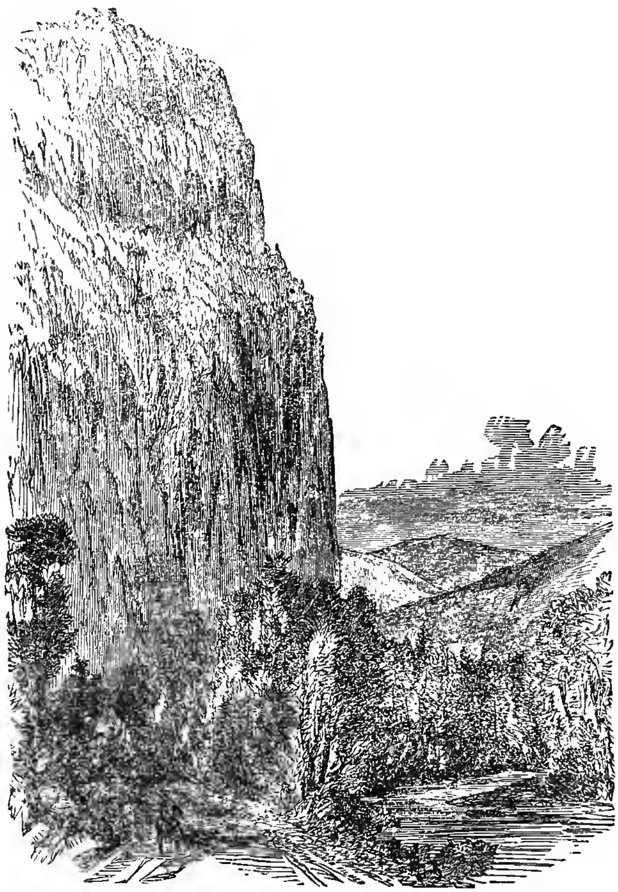
* Amer. Jour. Sci. II, Vol. L, p. 83. Presidential Address before American Association for the Advancement of Science, at Indianapolis, 1871.

Museum. I understand Dr. Jackson left a collection of rocks and minerals at Concord to illustrate his explorations. As they were entirely destroyed by fire a few years since, I have no means of ascertaining what their value may have been.



GRANITE LEDGE IN BARTLETT.

CHAPTER II.

HISTORY OF THE PRESENT GEOLOGICAL SURVEY.

AT the June session of the legislature in 1868, the following statute was enacted, as taken from Chapter III, Laws of 1868:

AN ACT to provide for the geological and mineralogical survey of the state.

Be it enacted by the Senate and House of Representatives in General Court convened:

SECTION 1. That the governor of this state, by and with the advice of the honorable council, is hereby required and authorized, as soon as may be after the passage of this act, to appoint a state geologist, who shall be a person of competent scientific and practical knowledge of the sciences of geology and mineralogy; and said state geologist shall have power to appoint such suitable person or persons as he may deem necessary to aid him in carrying out the purposes of this act.

SEC. 2. It shall be the duty of said state geologist, as soon as may be practicable after his appointment, to commence and carry on, with as much expedition and dispatch as may be consistent with minuteness and accuracy, a thorough geological and mineralogical survey of this state, with a view to discover and examine all beds or deposits of ore, coal, clay, marls, and such other mineral substances as may be useful or valuable, and to perform such other duties as may be necessary to complete such survey.

SEC. 3. It shall be the further duty of said state geologist to make a brief annual report of his progress to the secretary of state, who shall submit the same to the legislature, and shall forward from time to time such specimens of mineral substances as may be proper and necessary to form a complete cabinet collection of specimens of the geology and mineralogy of the state, as follows, viz.: One complete set to the secretary of state, for preservation at the capitol of the state, which shall be so classified and arranged as to be accessible to all interested in the mineral capacity of the state, and one complete set to the museum of the agricultural college, to be used in the instruction of the young men who may resort there for an agricultural education.

SEC. 4. Whenever said survey shall be completed, a report of the same, accompanied by such maps and drawings as may be necessary to elucidate and exemplify the same, shall be published under the direction of said state geologist.

SEC. 5. That, for the purpose of carrying into effect the provisions of this act, the sum of thirty-five hundred dollars ($3,500) is hereby annually appropriated, to be expended under the direction of the governor and council.

SEC. 6. This act shall take effect from its passage.

[Approved July 3, 1868.]

OFFICIAL PUBLICATIONS.

First Annual Report upon the Geology and Mineralogy of the State of New Hampshire. By C. H. Hitchcock, State Geologist. 12mo, 36 pp., 1 map. Manchester: John B. Clarke, State Printer, 1869.

Second Annual Report upon the Geology and Mineralogy of the State of New Hampshire. By the same. 8vo, 37 pp., 1 map. Manchester: John B. Clarke, State Printer, 1870.

Report of the Geological Survey of the State of New Hampshire, showing its progress during the year 1870. By the same. 8vo, 82 pp. Nashua: Orren C. Moore, State Printer, 1871.

Report of the Geological Survey of the State of New Hampshire, showing its progress during the year 1871. By the same. 8vo, 56 pp., 1 map. Nashua: Orren C. Moore, State Printer, 1872.

Report of the Geological Survey of the State of New Hampshire, showing its progress during the year 1872. By the same. 8vo, 15 pp., with heliotype map. Nashua: Orren C. Moore, State Printer, 1873.

Mt. Washington in Winter, or the experiences of a scientific expedition upon the highest mountain in New England—1870–71. 12mo, 363 pp. Boston: Chick & Andrews, 1871.

Besides these, there have been a few papers read by the state geologist before scientific associations, and subsequently published, relating to New Hampshire geology, unfolding more fully than is possible in the annual reports our ideas of the stratigraphical structure of the state. In fact, the act specially forbids the presentation of observations at great length, and therefore we have felt constrained to make the reports very brief. Our investigations have led to the adoption of new views respecting the geological features of New Hampshire, which seem of considerable importance. They will be unfolded in detail in the volumes now in course of preparation; and we must be content at the outset to give a short sketch of the operations of the survey, as set forth in the annual reports of progress,

partly to trace the rise of the doctrines adopted after much reflection, and then present the various physical features which lie at the base of sound geological reasoning.

New Hampshire, in her geographical position and topographical contour-features combined, is unlike any other portion of our land; and, therefore, it is appropriate to state at the outset what there is peculiar about her topography, climate, distribution of animal and plant life, scenery, variation of the magnetic needle, and other points in physical geography. These involve a history of the artificial boundaries of the state, notices of maps that have been published, a brief review of scientific explorations among the White Mountains, a sketch of the theories relating to the elevation of mountains, earthquakes, and the conclusions that we have now attained respecting the physical history of the state, or an account of our territorial limits in the several periods of geological time. This chapter might be styled an epitome of the geology of New Hampshire.

THE FIRST THREE MONTHS OF LABOR.

The first annual report presents a sketch of the labors of three months in the field, and is not, properly speaking, an *annual report*. On the eighth of September, 1868, I had the honor to receive from His Excellency Walter Harriman, governor, the notice of my appointment as state geologist. Though almost too late in the season to commence work, I thought something might be done, and began the examination of the Ammonoosuc gold field. On the ninth of September I started for Lisbon, stopping on the way at Hanover to arrange for an office and storage apartment for specimens. As a part of our work, invitations were issued through all the newspapers of the state, to persons interested in minerals, to communicate information and forward specimens of interesting and valuable substances for examination. About eighty answers have been received to this appeal, from first to last, communicating many facts of great importance, as well as specimens. The great success of this circular has satisfied us that the community have been watching the progress of our work with much interest; and that those who have been living among the rocks and hills of New Hampshire will not be satisfied with the

economical results of the survey, but are anxious to understand the causes of the elevation of the mountains, of the immense foldings and erosions of the solid ledges, the filling of the rock crevices with metallic ores, and the formation of the soils.

As soon as possible our corps of observers was organized by the appointment of George L. Vose of Paris, Me., and J. H. Huntington of Norwich, Conn., as assistant geologists, and of Prof. E. W. Dimond of Hanover, as chemist.

Unforeseen circumstances prevented either of the geologists from entering the field till the spring of 1869. It seemed best to give each of them a special subject, or a definite area, to investigate. Accordingly the White Mountain region was assigned to Mr. Vose, and the principal part of Coös county to Mr. Huntington. Mr. Vose was expected to pay special attention to the topography, and, in addition to the delineation of the geological structure, to furnish the most accurate map of the mountain region ever drawn.

Inasmuch as Professor Dimond has been continually occupied by other matters, he has not been able to act as chemist for the survey at any time. His place in this respect has been supplied by Professor Charles A. Seely, of New York, and also, to a small extent, by Professor B. T. Blanpied, of the New Hampshire College of Agriculture and the Mechanic Arts.

The third month's exploration was in May, 1869. Its beginning found Messrs. Vose and Huntington, with myself, in the field, engaged in determining the limits of the gold field in the towns of Littleton, Lyman, Lisbon, Bath, Monroe, Landaff, and Haverhill. There has been little modification of the results attained at that time, save in greater precision; and no portion of our territory has received so much attention as this.

The report proceeds to give the history of the discovery of the gold in this valley; a full description of the Dodge gold mining property, with assays; a notice of other supposed auriferous openings, with an affirmative answer to the question whether it will pay to mine for gold in New Hampshire. All these points will be again stated, with additions.

In this pamphlet there appears a colored geological map of the most interesting part of the gold field, in which, with the accompanying descriptions, may be discerned the germ of our peculiar notions respecting the

structure of all New England. A portion of the map was enlarged, and hung upon the wall of a room at the state house, near a case of specimens, where those who were interested in the subject could judge of the correctness of the conclusions.

The description states that "there are two general divisions upon the map: first, the granitic and gneissic rocks, *which appear to be older, and consequently to underlie the formations of the second or Quebec group.*" Explanation is then made of the term "Quebec group," and its use in the sense in which it was proposed by Sir W. E. Logan stated to be "provisional, and liable to amendment after further explorations shall have made our knowledge more definite."

The historical importance of the description of the map leads me to quote it:

A mere glance at the map and accompanying section suggests two conclusions: First, there is an unusual expansion of the area occupied by the gold rocks north of Haverhill, which contracts to some extent in the latitude of Littleton. The narrowest part of the group can be seen by referring to the Vermont Geological Map, and noticing the contracted band, not three miles wide, along Connecticut river. It is not over four miles wide in any part of its course between Lebanon and Woodville.

Second, the rocks assume the form of a basin or synclinal axis.* To confirm this view, appeal is made to the general arrangement of the several groups. In the centre is the auriferous conglomerate, with some of the upper schists. These are inclosed by a line of dolomite, not represented upon the map; this by clay slate; the slate by the lower green schists which occupy the outer edge of the basin, and adjoin the gneissic rocks of the White Mountains upon the east, and the calciferous mica schist or supposed upper Silurian strata on the west in Vermont. Hence the strata in the centre of the field, the conglomerate, slates, and upper schists lie at the summit of the series, and were the latest formed. A few words about each sub-division.

1. *Gneissic and Granitic.* These rocks consist of gneiss passing into mica schist and granite. They continue easterly from the gold-field past the White Mountains into Maine. By way of geographical convenience, they may be called the White Mountain series. The line of union is irregular, and the bordering rock is not uniform. In Littleton it is generally granitic; in Lisbon, gneissic; more quartzose in Haverhill. A bed of limestone skirts the border in Lisbon, and its place seems to be taken by soapstone in North Haverhill.

2. *Staurolite Rock.* Adjoining the gneiss, and apparently resting upon it, is a slate or schist (according to locality) filled with crystals of the mineral *staurolite*, called

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* Shown also farther north.—*Geology of Vermont, p.* 521.

staurotide in the older mineralogies. Garnets are also present. This rock has not been seen out of Lisbon and Landaff, and that which lies in Landaff is chiefly garnetiferous. More labor is required to fix the limits and proper relations of this rock. At almost any outcrop good specimens of staurolite may be obtained in abundance.

3. Next are *Argillaceous Schists*, passing into clay slate. This rock differs from clay slate farther west, and receives no color on the map to separate it from the next division. A line drawn from the south branch of the Ammonoosuc in Lisbon to the east line of Bath shows its western border. It may contain garnets and staurolite, and carries quartz veins worthy of examination for gold.

4. *Lower Schists*. These belong to the lower part of the Quebec group. They are chiefly a greenish, unctuous schist, sometimes massive, the same with that usually called "talcose schist." As the unctuous character seems to be derived from the alumina present, we shall often style them aluminous schists. Marked varieties occur over the wide area representing this division, as hornblende and chlorite schist, greenish quartzites, sandstones and conglomerates, white quartz, etc. Within it are beds of dolomite, limestone, buhrstone, the copper belt, and veins of iron pyrites. It would seem as if there were an anticlinal axis in the west part of the area of this group, followed by a synclinal in the east.

5. *Clay Slate*. This rock is abundant in the central part of the series, and carries the gold veins akin to the Dodge lead. That which lies in Bath is often grayish. Its distribution is quite irregular, and there are several patches of it, apparently outliers, in two of which are slate quarries. The dolomite next the conglomerate is frequently imbedded in this dark slate. In the more northern part of the dolomite, the rock is more schistose.

6. *Auriferous Conglomerate*. An immense number of facts of scientific interest in regard to this curious belt have been obtained, but their publication must be deferred. The rock is a clear quartz conglomerate, from ten to one hundred feet wide, extending from the east part of Lyman into Bath. As it can be readily recognized, and resists decomposition, it furnishes an excellent landmark by which one can discover the wonderful foldings, overturns, and dislocations in the strata. Instead of following a straight course, its line of outcrop is sharply tortuous, and a fault has often thrown the rock out of its line, in one case a distance of eleven hundred feet. These variations are shown in the large manuscript map spoken of above, and on the printed map, as well as the scale will permit, by the red line. That this rock overlies the slate, is shown by the general synclinal character of the country, and its encirclement by the clay slate which both accommodates itself to the very tortuous course in Bath, and dips beneath it on the east, south, and west sides.* That it overlies the lower schists seems proved by the presence in it of pebbles of quartz containing chlorite, jasper, and buhrstone, all of which have been observed exclusively in that member.

7. *Upper Schists*. These are partly very light colored, and partly quite siliceous as

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* This view has been modified by later reseaches.

well as unctuous. They bound the clay slate on the west side, near the Dodge mine; while near their eastern limit is the auriferous quartz vein described as the property of the New Hampshire Gold Mining Company. The color and aspect of this group change in proceeding southerly.

8. *The Copper Belt.*

Upon the map is a section from Bronson's lime-kiln to the Connecticut river, near Stevens village, in Barnet. The dips and general arrangement are the same with what will be described hereafter. Two faults are represented, whose extent, but not existence, may be somewhat modified in future descriptions.

Copper Mines. Next, a considerable space is devoted to a description of numerous copper veins, chiefly along Gardner's Mountain range. The general conclusions then reached have been confirmed by subsequent researches. Only the conclusions need be referred to in this sketch, as the details will be given hereafter.

In brief, it may be said of the Gardner Mountain range of copper veins, that they consist of schists charged with the sulphurets of iron and copper, averaging less than five per cent. before concentration; that they are conveniently situated with respect to drainage and to water-power. As several mines are contiguous, adits, mills, and tramways might be constructed for the mutual benefit of several proprietors, with a comparatively small proportionate outlay for each. It was understood that some of these proprietors had arranged for the concentration of the ores at the new mills soon to be constructed in the west corner of Lisbon. The working of these copper veins, if conducted with prudence and wisdom, will undoubtedly be remunerative; and when the enterprise is fairly inaugurated, a large number of workmen will be employed, and a new impetus given to the industry of the whole community.

Miscellaneous Topics. Other topics treated of were the zinc or copper mine at Warren; the nature and extent of peat deposits; an enumeration of beds of limestone suitable for manufacture into quick-lime; agricultural deductions for the Coös region; economical statistics and statements about the museums. Great interest in the survey among the people was also spoken of. This manifested itself very pleasantly in acts tending to

forward our researches. Some hotel proprietors refused to accept of compensation for accommodation received; others reduced the ordinary rates for our benefit; many occupants of private houses freely tendered their hospitalities; some have gone with us to point out localities of interest; and for six weeks so many carriages were placed at our disposal that there was no occasion to hire a team. Every one with whom we came in contact, from highest to lowest, expressed an interest in our work, and no one, to our knowledge, spoke of it disparagingly. These many favors greatly stimulated us in our work. Acknowledgment was also made of the important aid furnished by the newspapers. They promptly circulated our original appeal for aid, and have always been ready to help us subsequently.

The authorities of Dartmouth college generously provided rooms to serve as an office and working apartment, as well as for the exhibition and storage of specimens, till a building could be erected for their accommodation. Lastly, a few names of individuals were given who had tendered us special courtesies.

Second Annual Report.

This continues the history from June 1, 1869, for one year. It commences with statements respecting the importance of a new topographical map of the state, that might serve for the proper delineation of the geological boundaries. One of the first inquiries made at the beginning of the New Hampshire explorations, related to the character of the maps in use, that I might learn with how great precision the position and courses of the several mineral veins and rock deposits could be delineated. I found that a map had been issued, under the authority of the state, in 1816, by Philip Carrigain. This seems to have been a very fair delineation of the natural and civil boundaries at the time of its appearance. But there are serious errors in it of latitude and longitude. Nearly half the boundary lines have since been altered, whether of the towns, or the limits between adjoining territories; and, moreover, the plates are not to be found. Then the whole face of the country has been altered since 1816; large tracts of forest have been reclaimed and occupied by village sites; numerous roads and railroads have been constructed,—so that Carrigain's map does not meet the necessities of either practical or scientific pur-

poses at the present day. There have been smaller maps also constructed, most of which are inferior to Carrigain's for accuracy, as they certainly are in the style of execution.

Besides this, other map material exists. There are, first, the county maps, prepared chiefly by Prof. H. F. Walling, at an expense of over $20,000. These present the roads with great accuracy, and likewise the names of the owners of every house at the time of the surveys. Being on a large scale, and published mostly about 1860, the boundaries and names agree essentially with what they are at present, and the surveys were quite accurate. Secondly, a considerable triangulation has been effected by the United States Coast Survey over fully a third part of the state. By means of their triangles a score or more points are definitely fixed in respect to latitude and longitude, and that as correctly as is possible, through the unequalled accuracy of the Coast Survey engineers. Thirdly, there exists a very careful delineation of the boundary between New Hampshire and Canada, prepared in 1844, under the direction of the governments of the United States of America and Great Britain, Colonel Graham being the commissioner on the part of the United States. Lastly, there are the reports of commissioners concerning the boundaries between New Hampshire and Maine, between New Hampshire and Massachusetts, and there are two local maps of the White Mountain region, all of which are accessible.

On further inquiry it was ascertained that in 1853 the legislature appointed a commissioner to report upon the expediency of preparing a new topographical map of the state. The report was presented the following year by Prof. John S. Woodman, of Hanover, who briefly recited the errors in Carrigain's and other maps, and carefully estimated the expense of preparing a new draft based upon the government work just alluded to, and upon new surveys. He showed that such a map would involve an expense of thirty or forty thousand dollars. No action was taken upon this report by the legislature.

It appeared to me that the chief part of the surveys requisite for the proper delineation of a new map of the state had been made since 1854, so that by a careful collation of the abundant material, coupled with some additional triangulation and river surveys, a new map might be prepared, sufficiently accurate for all practical purposes, which would require a very

small appropriation compared with the sum estimated by the commissioner in 1854. A letter was accordingly addressed to His Excellency the Governor, and the Honorable Council, in which the foregoing facts were recited, and the proposal was made that, without asking for any additional appropriations, the geologist would cause a new map of the state, upon the scale of two and a half miles to the inch, to be prepared, and that this work might be considered as involved in the act authorizing the survey. The council approved of this proposition May 13, 1869; and since that time measures have been taken to prepare the map, in connection with the other work.

Topographical Work Performed.

The most important topographical work performed this year is embodied in a report by Prof. E. T. Quimby, of Dartmouth college, most of which is presented in the chapter upon topography.

Next should be mentioned the labors of Mr. Vose. He spent a few weeks among the White Mountains, taking a large number of observations for the purpose of fixing the exact position of many of the high mountain peaks. His observations serve to fix the latitudes and longitudes of Mt. Passaconnaway, Waterville; Mt. Pequawket, Chatham; Mt. Whiteface, Waterville; and Mt. Chocorua, Albany. From Mts. Pequawket and Chocorua, Mr. Vose drew accurate sketches of all the mountains as seen along the New Hampshire horizon. The instrument used was a six-inch theodolite, kindly loaned for the purpose by the United States Coast Survey. Mr. Vose also made observations upon the geology of the region, which were mostly printed in the report for 1871. In the month of August he resigned his position on the survey.

During all the seasons of field work our parties have been supplied with county maps, and have carefully noted the changes or alterations required for the perfection of the general map. These will be embodied upon our large geological map. For the sake of determining the formations in the Ammonoosuc gold field with accuracy, we commenced during this season a topographical survey of a few square miles of the most valuable portion, upon the scale of five hundred feet to the inch. With the aid of J. H. Huntington, A. C. Page of Center Harbor, and A. A.

Woolson of Lisbon, two square miles of the territory were surveyed. The intention was to set stakes at the corners of every block of five hundred feet square, and thus to locate the formations with great definiteness.

At the request of the commissioners appointed to consider the propriety of establishing a survey of the water-power of New Hampshire, we prepared a map of the state, upon the scale of ten miles to the inch, showing by colors the areas drained respectively by the Connecticut, Androscoggin, Saco, Piscataqua, and Merrimack rivers. It was compiled from our data by Mr. Huntington. The map accompanied the report of the hydrographic commissioners. A copy from the same plate, with changes and additions, was presented with our second report, designed to illustrate the distribution of the granite and the progress of our triangulation, as well as some of the geological formations.

Measuring Heights.

In May, 1870, a trip was taken by Mr. Huntington to determine the relative altitudes of the passes along the principal White Mountain range between the Crawford house and Waterville. The snow had not entirely disappeared, so that the expedition was of a very laborious character. The results are given elsewhere.

A thorough knowledge of the general elevation of the land of the state being very important, measures were taken early towards the obtaining of exact altitudes in the interior. Upon examining various railroad surveys, discrepancies appeared, so that they could not be relied upon. Two lines of survey running lengthwise of the state were therefore devised,—one from Portsmouth (or Great bay) through Manchester, Concord, and the Connecticut valley to Connecticut lake; the other from Lowell, Mass., to connect with the other survey at Lancaster. The final conclusions appear in another chapter; but the work was commenced early in the second season. Messrs. Frank and H. D. Woodbridge, of Dartmouth college, obtained, by actual levelling much of the way, facts which fixed the height of the barometer at the Shattuck observatory, in Hanover, at 603.71 feet above mean tide-water. A few computations were made, also, by a comparison of barometical observations at the Shattuck observatory, and the top of Mt. Moosilauke.

Mountain Explorations.

During the second year, the Moosilauke winter exploration was carried out by J. H. Huntington and Amos F. Clough. This is sketched, as fully as needed for our purposes, in the chapter upon the history of explorations among the White Mountains.

Possibly there may be space, in the chapters upon scenery, to quote from Mr. Vose's report upon an ascent of Mt. Carrigain, made during this year.

Measuring Sections.

In a letter directed to Rev. Dr. Asa D. Smith, President of the New Hampshire College of Agriculture and the Mechanic Arts, and printed in his report for 1869, I set forth my views as to the best method of exhibiting the specimens of rocks collected during our explorations. It was suggested that these should be collected along lines about fifteen or twenty miles apart, running east and west, and parallel to one another, amounting to fourteen in number in all. These lines were called lines of section, because it was proposed to show, in connection with the specimens, a geological profile and section. This method of studying the geological structure of the state readily commends itself to every mind.

We crossed the state eight times during this season in endeavoring to measure these sections. The lines of section thus measured are,—

I. From Lawrence, Mass., along the south border of the state, to Connecticut river.

II. From Seabrook to Chesterfield.

III. From Portsmouth to Walpole.

IV. From Great Falls to Charlestown.

V. From Milton to Cornish.

VI. From Effingham to Hanover.

VII. From Errol to Stratford.

VIII. From Atkinson and Gilmanton Academy grant to Stewartstown.

The last two were traversed by Mr. Huntington on foot, as they lie chiefly in the unbroken forest. Two sets of specimens have been collected along these routes.

Examination of Coös County.

One of the most laborious parts of our work accomplished this year has been the exploration of about six hundred and seventy square miles of territory, in the north part of Coös county, by Mr. Huntington. The country is mostly unsettled, and consequently travelling is restricted to the most primitive methods, and all supplies are carried on one's back. The same is true of all specimens collected, which were at least a thousand in number, from the forest region. But the information acquired has been most important. As will be seen by the map, the line has been clearly drawn between the White Mountain series of granitic or gneissic rocks, and the dark slates and schists of newer formations. The latter are sub-divided into eight different bands, and a county map has been colored to show them. Two matters of economical interest have been developed,—the first, the existence of alluvial gold along Indian and Perry streams; and the second, the existence of large beds of serpentine north of Carlisle's grant, a few miles south-west from the crown monument, at the angle between New Hampshire, Maine, and the province of Quebec. The latter is, of course, too remote to be available for the arts at present, though the time is coming when it will be used. The gold is not unlike that of Lyman, judging from the character of the underlying rocks, but more closely resembles that mined a short distance over the line, where J. H. Pope, member of parliament, of Cookshire, province of Quebec, has been profitably extracting gold by sluices for several years. Mr. Huntington's specimens are quite large pieces of shot gold, of the same purity with that obtained by milling in Lisbon. It is not improbable that the gold can be profitably extracted both from the soil and the rock near the extreme northern boundary; and the proprietors of the large tracts of land there would do well to expend a few hundred dollars in testing the value of these auriferous deposits.

Miscellaneous.

There are further remarks upon the agricultural character of lands along Connecticut river; operations of the gold mining company in Lyman and Lisbon; notice of Mr. Vose's report; the Carroll county lead

mine; other mining properties, particularly beds of pyrites in Croydon, Unity, Lebanon, etc.; G. A. Wheelock's researches about Keene; various brief excursions; and the map of Dalton.

It was stated in the first report that very material aid might be furnished us in our explorations if the proprietors of large tracts of land would aid us in tracing out the formations upon lands in which they feel an interest. This appeal was immediately answered by J. B. Sumner, Esq., of Dalton, who furnished the means for a careful survey of the township of Dalton. The work was performed by Mr. Huntington, who prepared a map of the township, on the scale of one hundred and six rods to the inch, showing the several formations, as well as the courses of the metallic veins and the location of mineral deposits. A copy of this was sent to Mr. Sumner, with an explanation of the significance of the several colors. The facts ascertained are all embodied in our general geological map.

THE NEW MAP OF THE SECOND YEAR.

The map of the state spoken of above showed several geological features, under the following headings: 1. White Mountain, or gneissic series. 2. Sienite group of Exeter and Dover. 3. Porphyritic granite. 4. Common granite. 5. Merrimack group. 6. Quebec group. 7. Coös group. 8. Calciferous mica schist. 9. Clay slates. The remarks made about them are here reproduced, in substance:

1. *White Mountain or Gneissic Series.* In our report of last year this term was used to indicate the general mass of gneissic and granitic rocks of the state, including designations three and four of the present map. It occupies four fifths of the area of the state; and it will be a leading object of our survey to discover the relations of the several members of the group to one another. It may not be amiss to state that the clue to the structure of the whole has probably been discovered, and that, by diligence and discrimination, it can be completely followed out. The practical advantages of this knowledge can hardly be overrated, since information will at once be afforded restricting the occurrence of valuable minerals to narrow areas, where the proper research will develop them. I refer to such minerals as the soapstone of Francestown, the pyrites of Sullivan county, the mica of Grafton, granites, limestone, feldspar, tin, lead, etc.

I am satisfied that the following are some of the subdivisions of this group, which further explorations will enable us to define with precision: 1, normal gneiss; 2, ferruginous gneiss; 3, granitic gneiss; 4, feldspathic mica schist; 5, andalusite gneiss;

6, chiastolite slates; 7, granite; 8, sienite; 9, porphyritic granite; 10, quartzites; 11, limestones; 12, soapstones. Little doubt remains as to the Eozoic or pre-Silurian age of this entire series.

2. *Sienite of Exeter and Dover.* There appear to be sienitic rocks of probable Laurentian age, equivalent to the Quincy sienitic group of Massachusetts, prominently exposed along the Boston & Maine Railroad, between Massachusetts and Maine, especially in the towns of Exeter and Dover. They form, apparently, an anticlinal mass, overlaid by the Merrimack slates.

3. *Porphyritic Granite.* Common granite full of large crystals of feldspar, generally from one half of one to two inches long, which give a checked appearance to the ledges. Some portions of it have evidently been injected; while the arrangement of the feldspathic crystals, in parallel lines, leads to the suspicion of stratification in other cases. The area is probably very irregular.

4. *Common Granite.* The granite of New Hampshire seems to have originated at five different periods. First are the (*a*) indigenous and (*b*) eruptive granites of the White Mountain series; second, the (*c*) indigenous granites of the Merrimack group, in which none of the eruptive class have yet been seen; third, the (*d*) indigenous and (*e*) eruptive granites of the Coös and calciferous mica schist groups.

5. *Merrimack Group.* This name was informally applied by my father to the mica schists, slates, and quartzites contained in the valley of the Merrimack river, in Massachusetts. They skirt the Exeter sienites in New Hampshire, lying in troughs, on the flanks of an anticlinal. They probably belong to the earliest Silurian series.

6. *Quebec Group.* Lower Silurian, according to Sir William E. Logan, and largely developed in northern Coös county, the Ammonoosuc gold field, and along the Connecticut river, chiefly in Vermont, to Bellows Falls.

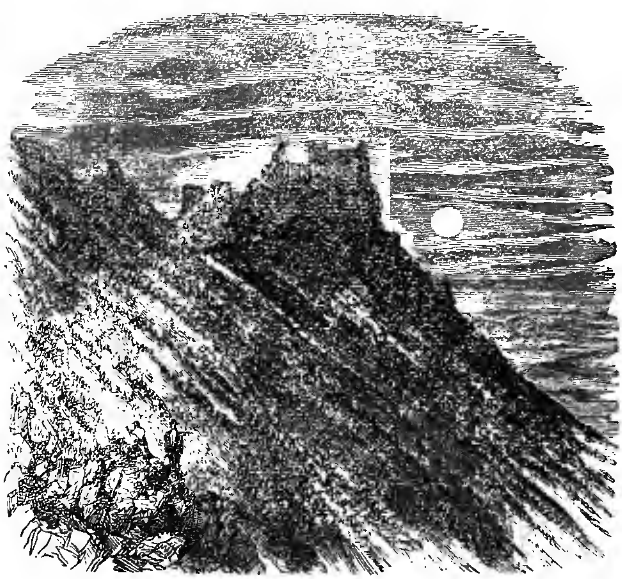
7. *Coös Group.* Under this appellation, for want of a better name, are included the argillaceous schists, whetstone mica schists, grits, etc., of northern Coös county, as explored by Mr. Huntington, the similar and associated rocks in Barford, Hereford, Auckland, etc., province of Quebec, and Essex county, Vermont, the quartzites, staurolite rocks, micaceous schists, hornblende schists, perhaps gneiss, protogine, and other rocks west of the White Mountain series and east of the Connecticut river, along the whole of western New Hampshire, but excluding the calciferous mica schist (8). The unity of the series, its age, thickness, and relations to the Quebec group, (8) remain to be defined. It appears clearly to overlie the White Mountain series unconformably. The calciferous mica schist and the clay slate groups seem to be limited outliers.

Acknowledgments.

The assistants of the second year were J. H. Huntington of Hanover, G. L. Vose of Paris, Me., Prof. E. T. Quimby of Hanover, Prof. E. P. Barrows of Middletown, Conn., T. M. Blossom of New York city, A. C. Page of Center Harbor, E. R. H. Hodgman of Mason, A. A. Woolson of Lisbon, and Prof. C. A. Seely of New York. The friends

who are specially mentioned as having aided the work were Hon. Samuel N. Bell of Manchester, H. H. Harriman of Warner, Hon. Moses A. Hodgdon of Weare, John J. Bell of Exeter, Prof. C. A. Young of Hanover, Dr. E. E. Phelps of Windsor, Vt., Geo. E. Jenks of Concord, Chase & Howe of the Winslow house, Wilmot, Daniel Pecker of Raymond, William Little and John A. Riddle of Manchester, George A. Wheelock of Keene, J. H. Pope, M. P., of Cookshire, P. Q., F. C. Jacobs of Connecticut lake, C. P. Richardson of Mason Village, Prof. S. C. Chandler of East Middlebury, Vt., Trustees of Dartmouth college, American Geographical Society of New York, Gyles Merrill of St. Albans, Vt., A. H. Perry of Lyndonville, Vt., George A. Merrill of Rutland, Vt., O. T. Ruggles of Fitchburg, Mass., R. Stewart of Keene, J. A. Dodge of Plymouth, G. E. Todd and H. E. Chamberlain of Concord, and George Stark of Nashua.

The report closes with a notice of the progress made in erecting a building at Hanover for the reception of one of the geological collections, and a request that a place might be fitted up for the reception of the other at Concord.



CASTELLATED RIDGE OF MT. JEFFERSON.

CHAPTER III.

HISTORY OF THE SURVEY—*continued.*

WE now reach an epoch in the history of our explorations when it may be more profitable to treat of the subjects of research each by itself, than to speak of the yearly progress in each. The time had arrived when we began to understand the structure of the White Mountains, which knowledge proved to be the key to that of the rest of the state. The field had been assigned to Mr. Vose originally; but his resignation left the place vacant, and it became the duty of the state geologist to explore the territory in person. The special plan pursued in 1870 may be thus described.

This laborious field of research includes particularly the region about thirty miles long and twelve or fifteen wide, bounded by Israel's, Moose, Peabody, Ellis, and Saco rivers. This area is nearly an unbroken forest, traversed only by the bridle-paths and roads required for the ascent of Mt. Washington by summer visitors. The plan pursued was, to visit systematically every one of the numerous peaks and valleys composing this area with the hammer and barometer. As the first result of our labors in the district specified, a physical model of the mountainous region was constructed, about five feet in length, on the scale of one hundred and forty rods to the inch horizontally, and one thousand feet to three fourths of an inch vertically. Contour lines were drawn for each five hundred feet, and were made the basis for fashioning the mountains. With our

limited resources, much reliance was placed upon estimates of the location of the contour lines, without actual measurement. Hence this model is only an approximation to a correct representation, but is sufficiently accurate to enable all interested in the study of the mountains to comprehend the relative altitudes and courses of the ranges, especially as they stand related to the distribution of the formations.

After the exhibition of this model in public, information was furnished that a model of the White Mountains had been fashioned in plaster, several years since, by Rev. Dr. Thomas Hill, lately president of Harvard college. This was upon a much smaller scale, about eighteen inches square, and was built up upon the basis of Bond's Map of the White Mountains, published in 1853. It includes the Franconia region, and all the mountains as far south as Waterville and Conway. An inspection of this representation shows great familiarity with the structure of the mountains, and it is a matter of regret that its existence has been known to so few persons. A copy of it has been presented to us by the author, and is placed in the state museum at Hanover.

So numerous were the localities requiring visitation, that six of the members of the class of 1871 of Dartmouth college, C. S. D., were invited to assist in the work of exploration. These were B. W. Andrews, W. B. Douglass, C. J. Johnson, J. F. Pratt, E. Thompson, and Frank Woodbridge. Aid was also furnished by J. H. Huntington, Dr. Nathan Barrows, and E. Hitchcock, Jr. We procured the necessary provisions and other supplies, and lived among the mountains, in extempore camps, till the various points had been explored and the required observations made. Without so many assistants, the early completion of the model would have been impossible; and all who take pleasure in contemplating the results are under obligations to these gentlemen for their very arduous labors.

That it is very difficult to climb high mountains is a statement which no one will deny. Most persons who visit our New Hampshire mountains are well satisfied with their labors when a single peak has been ascended on foot. They are willing to accept almost any theory that may be proposed to explain their geological structure, because immense labor would be required to disprove it. The task before us was the dissipation of all false notions, and the discovery of the real stratigraphical structure

of the rocky masses, by careful induction. The whole party were animated with the desire to accomplish this object, and therefore visited the almost inaccessible peaks and ravines, one after another, till all had been explored. The actual exertion often put forth for procuring a single specimen was greater than to pass over Mt. Washington on foot, by the paths. Its location may have been three or four thousand feet above the camp, and the country to be travelled was the original forest, never before traversed except by hunters, full of underbrush, fallen trees, and at the higher elevations consisting of the stiff dwarf spruces, through which travelling is almost impossible. After overcoming the difficulties of threading the forest and ascending the precipices, the rarified air of the upper regions has made even slight exertions burdensome. We take great pleasure, therefore, in pointing to the results of our labors, as they have been acquired only through infinite toil; and we feel sure that if our generalizations are not accepted, it will be a long time before any other party will labor so hard as we have done to disprove our theories.

A sketch of the various opinions that have been entertained respecting the age and structure of the White Mountains was presented at some length in the report for 1870; also, further definitions respecting the Coös group, and the manner in which the valley of the White Mountain notch had been excavated. The conclusions expressed concerning the stratigraphical structure have not been modified by subsequent explorations. The following opinion is expressed as to the age of the series:

In fine, the White Mountain rocks are believed to belong to two great systems, the Gneissic and the Coös group. The first are, for convenience, called the White Mountain series; and in the area of the model are various imperfect gneisses, verging into mica schists, a few beds of genuine gneiss, granitic gneiss, andalusite gneiss and granite, both bedded and in veins. These rocks appear to underlie the Coös group, and are therefore older. The presumption is that they are entirely Eozoic, though it is not clear whether they are to be considered as the equivalent of the Laurentian of Canada, or more nearly the age of the Cambrian of Great Britain, as restricted by the government survey.

This White Mountain series has a great development in the middle and southern parts of the state, perhaps embracing everything not included in the Exeter, Merrimack, and Coös groups. Its satisfactory reference to

the Eozoic series will enable us to clear up the obscurities of New Hampshire geology, and make the study of our strata as interesting as that of the well-established fossiliferous groups in other parts of the country.

White Mountain Explorations in 1871.

The most valuable of all our reports is that which details the operations for 1871. The conclusions stated had been foreshadowed by the results of the previous years' explorations, but were rendered much more satisfactory by our labors in the area lying between the Saco and Pemigewasset rivers, and north of Sandwich.

On the seventeenth of June, with the assistance of eleven gentlemen from the graduating class at Dartmouth college, the exploration of the Pemigewasset country was commenced, and continued uninterruptedly for a month. These gentlemen kindly proffered their services without charge, and deserve the thanks of the community for their exertions in our behalf. Some have imagined the party as enjoying the luxuries of the season in the cushioned seats of the well appointed hotels about the mountains, with every want eagerly anticipated by dutiful attendants. On the contrary, our houses were hastily extemporized sheds; our beds, a few boughs or ferns placed upon boards; our food consisted of stale crackers and preserved meats, save a rare taste of trout and berries gathered in climbing mountains, and the luxury of an occasional basket of provisions sent by kind friends at the Profile house; and we were our own servants. The party consisted of A. A. Abbott, M. O. Adams, A. M. Bacheler, R. M. Carleton, C. H. Conant, G. E. Davis, H. C. Harrison, C. W. Hoitt, Jonathan Smith, W. Upham, A. W. Waters. All these gentlemen contributed something towards the accumulation of facts bearing upon the important questions discussed in the first part of the report. Messrs. Conant and Smith were so fortunate as to discover a new lake on the north-west side of Haystack mountain, which we christened Haystack lake. It is parallelogramic in shape, fifteen rods long and half as wide, with rather shallow water, forming the head waters of Gale river, three thousand seven hundred and eighty-seven feet above tide-water, as determined by the aneroid barometer. Messrs. Abbott and Bacheler succeeded in discovering a second lake, still larger, upon the east side of Mt. Kinsman, named, as the other, after the mountain. Others of the

party measured the length of the profile of the "Old Man of the Mountains," finding it to be thirty-six feet from chin to top of the head,—the face itself being twelve hundred feet above the lake beneath. Soon after the disbanding of the first, a new party was formed, consisting of A. A. Abbott, W. Flint, and W. Upham, with the aid of E. C. Atwood for a short period. This second party remained, some of them, two months longer, exploring the country as far south as Sandwich.

Description of the Map.

With the report there appeared a geological map embodying the results of all our explorations. The colors upon the map indicated the geographical relations of ten groups. In the absence of precise knowledge, spaces were left uncolored in certain districts. The topographical basis is the map of C. H. V. Cavis, prepared for Eastman's White Mountain Guide, upon the scale of five miles to the inch, it being the most convenient one accessible to us. On account of the difficulties in the way of exploring among the mountains, which have already been described, this delineation can only be regarded as a reconnoissance, especially as the true position of the rocks did not suggest itself till late in the spring of 1872, when the field notes were being compared with specimens. The areas will be briefly mentioned, and the most important conclusions dwelt upon at length.

1. *Porphyritic Gneiss*. This is an ordinary gneiss, carrying numerous crystals of orthoclase or potash-feldspar, from a quarter of one to two inches long. The longer axes may be parallel to the strike, or arranged helter-skelter. It passes into granite with the same porphyritic peculiarity of structure. Its most northern area lies along the Ammonoosuc river in Bethlehem, Littleton, and Whitefield. Next, commencing west of Haystack mountain, at some unknown point, is another range, which passes southerly on the west flank of Profile mountain, and makes up the great mass of Kinsman or Blue mountain; thence passes southerly to Woodstock and Campton. It crops out on the west side of Moosilauke—how extensively has never been determined. A spur from this appears at the Lake of the Clouds on Mt. Lafayette, and passes southerly towards the Basin. It may occupy part of the uncolored area west of the Lafayette range. Upon the other side of the Pemigewasset country, this formation shows itself in the valley of Sawyer's river, on the south side of Mt. Carrigain. It is there covered by compact feldspar. It reäppears in Waterville, on Cascade brook, Snow's mountain, Bald Knob, and upon other high mountains in Sandwich, whence it passes out of the limits of the map. We suppose this to be the oldest formation among the mountains. Geologists speak of a rock of this character as common in the Laurentian, in various parts of North America and Europe.

2. *Bethlehem Gneiss*. The whole of Bethlehem is underlaid by a gneiss abounding in a talcoid mineral, perhaps pinite. The orthoclase is abundant, usually pink or flesh

colored, and mica is sparsely disseminated through the rock. It is usually granitic, so much so that it has always been called granite heretofore. Its most remarkable feature consists in the common east and west strike between Littleton and Cherry mountain. In Whitefield, Mr. Huntington finds the rock tending more north-easterly. Lying between outcrops of porphyritic gneiss, the natural inference is that it is a synclinal, and therefore newer, while the strike indicates a very great antiquity, judging from the same phenomenon elsewhere. The dip is monoclinal, averaging 75° northerly, across Bethlehem, but anticlinal in Whitefield. If the anticlinal structure is persistent, evidence may be afforded that this peculiar gneiss is older than No. 1. There is a limited outlier of this rock west of Haystack mountain, another north-west of Mt. Pemigewasset, a third about Big Coolidge mountain in Franconia, and perhaps another south of the east branch of the Pemigewasset. These limited outliers give the idea of a rock newer than No. 1. The boulders scattered to the north of Lafayette, in Franconia and Bethlehem, which Professor Agassiz regards as moraines of a local glacier pushing northerly, are composed of this rock.

3. *Gneiss.* The gneiss west of No. 1, in Franconia and Landaff, and also to a limited extent east of the Labrador felsite on Tripyramid, is a common variety, and has not yet been referred to any of the sub-divisions recognized elsewhere.

4. *White Mountain or Andalusite Gneiss.* This is the variety described in previous reports as containing andalusite or staurolite. It occupies the great part of the White Mountain area east of the Saco, making up the bulk of the highest peaks. It reäppears on equally extended a scale south of Mts. Pequawket, Chocorua, and Whiteface. About Dr. Bemis's residence, or the "Mt. Crawford house" of the map, this rock seems to be isolated, being surrounded by granite. A little of it lies to the north of the Labrador in Albany, and is not represented upon the map. Farther north it crops out in Whitefield, and there is a range apparently from the west flank of Profile mountain to Moosilauke. More is found in Thornton, and there is an extensive area of it to the south-west, which is not designated upon the map. The presumption is that the beryl-bearing gneiss east of the Pemigewasset, on the edge of Woodstock and Thornton, is the same rock which extends into Campton. The amount of andalusite in this area is very small. The relative position of the andalusite gneiss remains to be determined. It seems to be newer than Nos. 1 and 2, but its relations to the granites and felsites are yet to be made out.

5. *Common Granite.* The type of this rock appears at the Basin, Pool, and Flume in Franconia, and at Goodrich's falls in Jackson. The constituents are rather coarse, never more than an inch, and usually one fourth of an inch long. The orthoclase is commonly flesh-colored, and is the most abundant ingredient. The quartz is smoky, translucent, and often roughly crystallized. The mica is the least abundant of the three constituents, and is black. The joints passing through this rock are both horizontal and vertical. This rock seems to form the basis of the whole Pemigewasset country, and the areas left blank will most likely be found to consist of this same material. The first area is that in Franconia, embracing the Profile and Cannon moun-

tains, besides the parts already specified. The mountains show a finer grained rock than the valleys. Some of it seems to extend into the uncolored area between No. 1 and the Lafayette range. This probably connects under Flume mountain with the granites on the East Branch in Lincoln and Thornton. More appears near the forks of the East Branch, Hancock mountain, and the ridge north, including the falls in the valley of Mad river in Waterville, abundantly in the Swift River valley in Albany, and about Conway, passing under Pequawket, and extending into the Green Hills. The small area of Bald Face and Mt. Eastman in Chatham has a fine grain, and possibly is of a different age.

The largest area of this rock upon the map extends from Jackson to Carroll. The Saco valley above Rocky Branch is mostly excavated out of it. The excavation of the White Mountain notch out of this granite was alluded to last year. The high range north from Mt. Lowell to Mt. Willard is probably of this rock. East of the Saco the andalusite gneiss seems to have been cut by it, Mts. Crawford and Resolution being composed of granite. Mt. Deception, and the country east of the old Fabyan house, are made up of a different sort of a granite, whitish or grayish in color, with the feldspar in narrow crystals, porphyritic in appearance. But the range from the north end of Mt. Tom to the lower falls on the Ammonoosuc, and the three "Sugar Loaves" farther west, are entirely of the typical variety of coarse granite.

6. *Trachytic Granite.* Above No. 5, with the same horizontal appearance, is a granite of trachytic or semi-porphyritic aspect. The feldspar is orthoclase, as shown by analysis, and most of the rock is made of it, being essentially rounded crystals imbedded in a granitic paste, with scarcely any quartz, and rarely a peppering of dark mica. It often contains a small per cent. of manganese. The first great expanse of this rock lies between the saw-mill of Rounsevel & Coburn, in Carroll, on the Ammonoosuc, and Waterville. The Twin Mountains, Haystack, a portion of the Lafayette range beneath the cap, Mts. Liberty, Osceola, and other high peaks, are mainly composed of this trachytic granite. It will be observed that this area is wholly in the forest region, untraversed by roads; hence it is not strange that its peculiar characters should not have been recognized earlier. There is some of this rock north of Mt. Carrigain, and the Sawyer's Rock range appears to belong here. Other localities are high up Rocky Branch in Bartlett, Iron mountain, the valley of the Saco in Bartlett, underlying the great mass of Pequawket, but above the common granite. The rock referred to this division, along the Swift river and the Ossipee mountains, is made of finer materials, with more of the paste, and that of a darker color than the ledges farther west. It also disintegrates less readily.

7. *Brecciated Granite.* This designation applies to the rocks forming Eagle cliff in Franconia, and several nameless peaks between Profile and Kinsman. The fragments most easily recognized are those of porphyritic gneiss, dark gneiss, and hornblende, imbedded in a very compact feldspathic paste. Along Eagle cliff there are appearances of stratification, and at Echo lake the brecciated granite appears to underlie the porphyritic gneiss. The rock is irregular in arrangement, as if thrust

up from below. As it contains no fragment of the common or trachytic granite, we have concluded it to be more ancient than either of these granites, but newer than the porphyritic gneiss. The two areas are also probably connected beneath the Pemigewasset valley, under the common coarse granite, which either flowed in above the breccia, or was deposited upon it quietly in some other way.

8. *Norian.* This includes several areas of labradorite rock, including compact felsites, breccias, and sienites. They are the Lafayette range, Twin Mountain area, near Loon pond, Trypyramid region, Carrigain district, north of Mt. Tom, valley of Dry river, valley of Rocky Branch, Sable mountain in Jackson, Mt. Pequawket or Kiarsarge, Deer River valley in Albany, near Mt. Chocorua, and Red Hill, Moultonboro'. There are other areas to be referred to the same group outside of the White Mountain area.

9. *Clay slate and Quartzites.* The first of these areas is a limited one on the south slope of Pequawket; the second south-west of Mt. Willard, passing into andalusite slates and quartzites on Mts. Willey, Field, and Tom.

10. *Coös Group.* This embraces the andalusite slates on the east flank of the Mt. Washington range, repeated on the north-east side of Pine mountain, near Gorham, and the staurolite rocks from Littleton southwards, curving around the underlying Bethlehem gneiss. Only the eastern border of the latter is indicated upon the map.

White Mountain Explorations in 1872 and 1873.

A still larger party was organized for work in 1872. Under the direction of J. A. Leach, of Nashua, a plane-table survey was made of the south-west portion of the mountain area, with the design of perfecting the map. The rest of the party examined the rocks along the Saco valley and in Albany for a period of three weeks, under the guidance of Mr. Huntington. The explorations served to confirm the theory of the previous year concerning the arrangement of the formations. The parties consisted of the following members of the class of 1872, Dartmouth college: E. J. Bartlett, W. H. Cotton, L. G. Farmer, G. H. Fletcher, A. M. French, G. M. French, W. H. Galbraith, W. A. Holman, E. D. Mason, C. H. Sawyer, H. M. Silver, G. F. Williams, and T. W. D. Worthen; N. W. Ladd and A. O. Lawrence of the class of 1873.

In 1873 a few points about the mountains were visited by Mr. Huntington and myself for the sake of completing our knowledge of them. The exploration, so far as it seemed advisable to proceed with our present instructions from the state authorities, had been essentially completed in 1872.

The Labrador System.

The group of rocks referred by us to the Labrador system are first described in the 1871 report, and certain passages in the history of its exploration may be of considerable importance. The names of "Norian system" and "Norite rocks" were applied to this group in the report after a suggestion by Dr. Hunt. Upon reflection it seems more proper to use the first name suggested for the system, rather than the lithological appellation for a characteristic member.

The first locality described is in Waterville. Its discovery was due to the uncovering of the ledges by the remarkable rain-storm ending Oct. 4, 1869. The ravages of the freshet were described by Prof. G. H. Perkins, PH. D., of Burlington, Vt., who speaks of the ledge as a "black hornblendic rock." In May, 1870, Mr. Huntington went up the same stream and brought back specimens of the dark rock, which he thought might be labradorite. He carried a fragment of it to Dr. T. Sterry Hunt, of Montreal, for examination, March 21, 1871. Dr. Hunt wrote as follows concerning this rock to Mr. Huntington:

"The blue granular crystalline rock from Waterville, N. H., consists chiefly of a feldspar allied to labradorite. I have not separated the grains to get them quite pure, but the mass is seen under a glass to consist of the bluish-grey cleavable feldspar, with some mica, probably biotite, and a little magnetic iron ore. From a pulverized sample the magnet takes up about 5 per cent. of magnetic grains; these contain a little titanium. The analysis of the material thus freed from the magnetic portion gave me,—silica, 50.30; alumina, 25.10; protoxide of iron, 4.23; lime, 14.07; magnesia, 2.95; volatile, 0.70: loss (alkalies), 2.65=100.00. I have found the feldspar of the so-called labradorite or norite rocks very variable in composition, being sometimes more and other times less basic than typical labradorite." "The analysis agrees closely with what might be expected from an admixture of labradorite with biotite. It (the rock) may hold a little hornblende, but I did not discern any. Thus the rock agrees chemically and mineralogically with much of the norite of the labradorite series of rocks, in which titaniferous iron ore and biotite not unfrequently occur."

About the same time the following passage was written by Dr. Hunt in a letter to the state geologist. By oversight, the second passage was printed in a communication to the *American Journal of Science*, January, 1872, instead of the first. The error was corrected in the report for 1871.

"The specimen brought by Mr. Huntington is a labradorite or norite rock, which resembles in composition and aspect that of the Labradorian, with this difference, however, that it is much more tender and friable,—and, in this respect, resembles the granitic gneiss of the White Mountains, as compared with similar rocks in the Adirondacks."

I first visited the locality August 18 and 19, 1871, and subsequently on September 20, in company with Prof. J. D. Dana, LL. D., of New Haven, Conn. The conclusions derived from these two visits appeared in a short article by myself in the journal above cited, followed by descriptive analyses of some of the rocks by Mr. E. S. Dana, of New Haven, Conn. The description of the rocks agrees with that which appeared subsequently in the 1871 report, save in one or two particulars, which I will mention.

In ascending from "Beckytown," the first rock seen was called gneiss, with nodular orthoclase, with its supposed strata dipping by compass 80° S. 70° W. This rock is evidently the same with the "trachytic granite" of Mt. Osceola and elsewhere. After noticing its distribution in mass throughout so large a portion of the mountains, and its nearly horizontal position between the coarse granite below and the felsites above, the presumption arises that these so-called strata may be bands of mica whose planes do not correspond with those of accumulation, but have been superinduced during the metamorphism of the rock. The jointed planes, dipping about 25° westerly, would be those of stratification, if the rock is stratified. These were pointed out by J. P. Lesley.*

A few rods up Norway brook appears the first ledge of the ossipyte. Its junction with the gneiss is concealed by drift. For about a mile similar ledges occur, some exposures being sixty or seventy feet long. Considered as an isolated case, it is difficult to determine the planes of stratification, since two prominent sets of jointed planes exist, either of which might be taken for strata. One set dip about 20° northerly, and are the most numerous; the other dip about 75° W. 10° S. As the latter correspond better in position with the supposed strata of nodular gneiss, it was thought they indicated the proper lines of deposition. The former, however, are what appear at the first glance to be the strata; and, as by this interpretation the position of the rocks at Waterville will

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correspond with that in Franconia about the Lafayette range, our former ideas must be modified. We should have, therefore, an underlying granite, as seen in Mad river two miles below Greely's hotel; then the trachytic granite of Osceola, extending to the cascades and including the "nodular gneiss" on Norway brook, dipping gently westerly; and finally above both, the ossipyte schists, with a small inclination.

Mr. E. S. Dana has carefully analyzed specimens of the Waterville rocks, and described the assemblage as a new rock, with the name of *Ossipyte*, after one of the aboriginal tribes of Indians formerly dwelling in the neighborhood.

The following are his results with the ossipyte, it being composed of the two minerals, labradorite and chrysolite:

1. LABRADORITE.

	I.	II.	III.	Mean.
SiO_2	51.04	51.02	....	51.03
Al_2O_3 (TiO_2)	26.34	26.07	....	26.20
Fe_2O_3	4.79	5.13	....	4.96
CaO	14.09	14.23	....	14.16
NaO	.....	.....	3.44	3.44
KO	.....	.....	.58	.58
				100.37

The large percentage of iron (determined volumetrically) had not been expected, as the eye had failed to detect any impurities in the fragments selected for analysis. Some very thin pieces were afterwards examined under the microscope; and by this means it was found that even the clearest pieces contained very minute grains of an iron ore, from $\frac{1}{50}$th to $\frac{1}{200}$th of an inch in diameter, which were strongly attractable by the magnet. Microscopic dark specks less than $\frac{1}{10000}$th of an inch in size were also observed, and at first referred to the same cause; but, on magnifying them 800 diameters, it was concluded that they were air-cavities in the structure of the feldspar, and not any foreign matter. The peculiar dark smoky color of the rock is doubtless to be explained by the presence of these particles of iron ore.

This magnetic iron ore, a sufficient amount for the test having been picked out by the magnet, gave a decided reäction for titanic acid.

2. CHRYSOLITE.

	I.	II.	Mean.
SiO_2	38.82	38.88	38.85
Al_2O_3	tr.	tr.	tr.
FeO	28.00	28.15	28.07
MnO	1.12	1.36	1.24
MgO	30.88	30.36	30.62
CaO	1.26	1.60	1.43
	100.08	100.35	100.21

The oxygen ratio of the bases and silica afforded is nearly 1:1, and of the iron and magnesia about 1:2; whence the formula $(\frac{1}{3}\dot{Fe}+\frac{2}{3}\dot{Mg})_2\dddot{S}$. This is then a chrysolite, containing an unusually large per centage of iron (here a constituent of the mineral, and not owing to the presence of impurities). The amount of iron is not strange, considering the fact that the rock contains, diffused throughout it, so much free iron ore.

This chrysolite has the same ratio deduced for hyalosiderite, but still differs widely in fusibility and other characters. It is, in fact, a true chrysolite in all respects, while hyalosiderite is a doubtful compound, probably owing its fusibility in part to the potash present. B. B. the chrysolite is nearly infusible.

The following is Mr. Dana's analysis of another specimen of labradorite:

This feldspar has a grayish-white color, is destitute of iridescence, and only careful searching reveals any striations. Two analyses afforded,—

	I.	II.	III.	Mean.
SiO_2	52.15	52.36	....	52.25
Al_2O_3	27.63	27.39	....	27.51
Fe_2O_3	1.09	1.07	....	1.08
MgO	.92	1.06	....	.99
CaO	13.10	13.45	....	13.22
NaO	....	....	3.68	3.68
KO	....	....	2.18	2.18
				100.91

Both analyses show that the labradorite of this region is remarkable for the large proportion of lime present.

The next point in the history of these rocks in New Hampshire relates to a discussion respecting the discovery of the mineral aggregate named "ossipyte." In a letter of May 1, 1872 (which, with Prof. Dana's, is published in full in the report for 1871), Dr. Hunt speaks thus concerning Mr. E. S. Dana's paper: "He remarks that a rock consisting of labrador with chrysolite (olivine) has not been previously described. It was, however, long since noticed by Macculloch in Skye, and by G. Rose at Elfdalen. [*Senft die Felsarten;* also, Geology of Canada, p. 650.]"

The substance of this note having been communicated to Mr. Dana, the following letter came from his father:

PROF. C. H. HITCHCOCK.

My Dear Sir—In the absence of my son, Mr. Edward S. Dana, now on his way to Europe, I write a brief reply to your letter of the 29th inst. You stated that Prof. T. Sterry Hunt, in a recent note, objects to Mr. Dana's remark that a rock of the composition of the ossipyte of Waterville had not before been described, and that he refers to Macculloch as having observed the same in Skye, and G. Rose another example of it at Elfdalen in Sweden. Mr. Hunt is evidently unaware of the facts. Macculloch

found chrysolite in Skye, according to his two articles in Vols. III and IV of the Transactions of the Geological Society of London, only in trap or "amygdaloid;" and he repeats the same essentially in his work on rocks, the chrysolite being spoken of as occurring in an eruptive or overlying rock. Greg and Lettsom, in their work on British Mineralogy (1858), confirm this by speaking of the chrysolite of Skye as being found in *trap*. Moreover, the chrysolite is one of three constituents,—the other two being hornblende or augite, and a feldspar; and the rock is not Laurentian or Norian.

The rock of Elfdalen is undoubtedly related to that of Waterville, and yet is widely different. I have not seen Rose's description of it. But Senft, to whom Mr. Hunt refers, speaks of it as a hypersthene rock, that is, a granular compound of labradorite and hypersthene, with grains of chrysolite as an accessory ingredient. The ossipyte, on the contrary, consists almost solely of labradorite and chrysolite, there being "only a very little of a black mineral, probably hornblende." I examined the specimens of ossipyte with Mr. Dana,—the same that I collected when in Waterville with you,—and through much of it could detect no hornblende whatever. Mr. Dana was right, therefore, in saying that this Waterville rock, consisting essentially of labradorite and chrysolite, is one not previously described. The principal constituent, besides the two mentioned, was the titaniferous iron ore, which he found distributed in microscopic grains through the labradorite.

The light colored rock, from a point higher up the stream, determined to be a labradorite rock by Mr. Dana, is, as he observes, wholly different from the ossipyte, it containing much hornblende and no chrysolite; and the titaniferous iron ore in visible grains, instead of invisible particles disseminated through the labradorite.

After the publication of these letters, Dr. Hunt writes to the effect that he had personally examined Macculloch's specimens in Europe, and felt confident that the rock of Skye was the same with that from Waterville. *Per contra*, Prof. Dana communicates a message from Prof. Geikie, director of the geological survey of Scotland, in which it is stated that the rock of Skye is an eruptive rock related to trap. Whatever may be the truth as to the Scottish rock, it is clear that no one had proposed any technical name for this mineral aggregate before Mr. Dana; and therefore, by the canons of lithological nomenclature, the designation of "ossipyte" is entitled to recognition and acceptance.

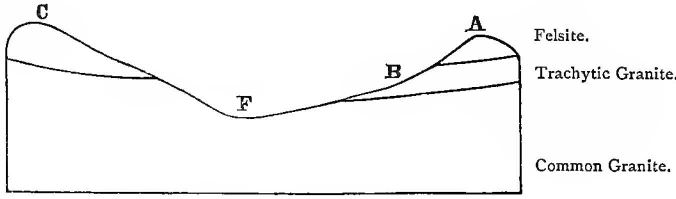
The 1871 report contains a full description of this locality at Waterville, and an enumeration of the other localities of the same formation. These are Sabba Day and Down's brooks, Waterville; Loon pond, Woodstock; Lafayette range; Mt. Tom; Mt. Washington river; and Sable mountain, in Jackson. These are the only ones in which the mineral labradorite had been found in the area of the map.

Discovery of the Succession of Members of the Labrador System.

The same report contains the announcement of the discovery of the relations to one another of the several members of the Labrador group, and also to the underlying porphyritic gneiss, White Mountain series, and brecciated granite.

From a peak north of Mt. Lafayette in Franconia to Flume mountain, there seems to be a nearly continuous band of dark, compact feldspar, about five miles long, and never more than two hundred to three hundred feet thick. It closely resembles some of the compact labradorites. The layers are horizontal, or nearly so, resting upon trachytic granite throughout. It has not actually been traversed from the south end of the Lafayette ridge to Flume mountain, but the topographical features of the country are such as to render probable its continuance by a curve to connect with that which has been observed upon the latter summit. The annexed wood-cut will show the relative position and thickness of the rocks between Mt. Liberty (C) and Mt. Flume (A), two thousand two hundred and fifty feet above the bottom of the valley. There is the common coarse granite at the base, the celebrated Flume of Lincoln (Franconia), lying at the bottom of the valley (F in the figure), eighteen hundred and forty-nine feet above the ocean. Above the Pemigewasset river there may be six hundred feet thickness of this rock, considering it to lie horizontally, before reaching the trachytic variety. This in turn may be one thousand feet thick, as shown at band C. This rock caps Mt. Liberty, but the compact feldspar has been spared by the denuding agencies upon Mt. Flume. As seen by the general map, the edges of this dark rock everywhere rest upon the trachytic granite.

Fig. 2.



Section across the Flume.

Mt. Pequawket.

The same granite which appears at the Flume, is found in the Green Hills, and all along through Conway, at Kiarsarge village, and in the lower part of the mountain itself. Above this the trachytic granite occurs upon all sides most distinctly (the fourth had not then been explored). It is not abundant on the south and east, but very characteristic. On the south, it crops out on the hillside below the slate. About five hundred feet above the south base of Pequawket, and in the old foot-path (that of 1840), occurs a ledge of clay slate, directly above the granite. This formation does not seem to extend far, as it is not found in either of the new paths up the mountain, and a very short distance from its lower boundary we pass beyond it and come upon the rock of which the upper two thousand feet of Pequawket appears to consist, viz., an igneous felsite, full of pebbles. The greater portion of the included fragments are angular, slaty, lying at all angles, and range in size from an inch to a foot in diameter; but the pebbles, many of them rounded, also occur very frequently, and were all taken from the rock in place. The slate above referred to runs N. 70° E., S. 70° W., and dips 50° to 80° N. W., being much twisted on a small scale. It does not appear either in the old or new roads, but in the path of 1840. Five hundred feet north and south and one thousand feet east and west seem to include the whole exposure, though further examination may detect it elsewhere. The upper part of Pequawket shows two well marked systems of joints, which seem to affect nearly the whole mountains. At the top, one set runs S. 60° W., and dips about 80° N. W.; the other set runs N. 55° W., and dips about 80° S. W. It will be observed that the first set agree almost exactly with the strike and dip of the slate in the lower part of the mountain. In many places on the upper part of the mountain the rock has a thin bedded sort of structure parallel to the jointed planes; but whether these divisions indicate a real highly inclined bedding remains to be seen.

The slate lying above the trachytic granite is, in this respect, like the felsites of Pemigewasset, but, unlike them, has been much twisted, and reposes on the top of the terrace, inclined at a high angle. No doubt would be entertained respecting its very much later origin than the upper two thousand feet of the mountain, except that the latter is partly com-

posed of fragments of slate, evidently derived from this formation. The lower portions adjacent to the slate are chiefly composed of it, and even at the summit small dark pieces, apparently of the same material, abound. A similar rock with dark fragments is found on Twin mountain. The composition of the cement shows it to be allied in character to the felsites elsewhere found overlying the trachytic granite.

A somewhat similar slate occurs between Mt. Willard and Mt. Field. Specimens from the two localities are not distinguishable from each other, and the mass of Mt. Willard is a trachytic granite. These slaty rocks pass into quartzites, if not into felsites, and cover a considerable area, including the country from Mt. Willey to beyond Mt. Tom, over three miles. Well marked crystals of andalusite are found in a similar slate on the north-east spur of Mt. Tom, which seems to ally the series with the andalusite slates of the Coös group along the head waters of Ellis river, at the east side of Mt. Washington. I observed that jointed planes existed in the trachytic granite parallel with the slaty strata above them on Mt. Willard, like those described upon Pequawket. Passing to the first peak of Mt. Field, the line of union of the granite and slate was traversed, having a compass course of N. 25°.W. In the saddle of Mt. Field the slates dipped 50° S. 20° W. But on the mountains south nothing is found to correspond with the feldspathic and brecciated cap of Pequawket. The relations of this slate to the granite and felsites demand further examination.

Relative Position.

A few considerations will serve to indicate the probable relative positions of the rocks that have been described. The sections given of the common granite, trachytic granite, and the felsites, seem to determine their relative positions, the last being at the top. The brecciated granites of Franconia appear to be older than any of these, and to underlie them, as already stated; and hence there may not be any correspondence between them and the breccias made up of felsites and labradorite. If these points are assumed, the porphyritic gneiss can be shown to be at the bottom of the series, for it lies outside of the lowest of them. Two principal ranges of this rock enter the limits of our map. The eastern

is cut off abruptly by the Labrador system at Waterville, crossing at an angle of at least seventy degrees, and as much as fifty degrees in the dip. Another exposure of the same band of gneiss appears at the base of Mt. Carrigain, standing nearly vertically. Passing from this across to the western range, we travel fifteen miles. An anticlinal is hardly supposable over so great a distance. The dips have not been observed systematically; but the western range, from the Pemigewasset to Moosilauke, has an anticlinal form, and comes up again west of Moosilauke so as to underlie a synclinal mass of andalusite schist or gneiss. This structure agrees with its position, as deduced from other facts. The andalusite rock is repeated east of the Pemigewasset in an anticlinal way, so as to correspond, as shown by its distribution on the map.

The porphyritic gneiss west of Echo lake dips north-westerly. At the Lake of the Clouds the dip was not measured. On the ridge running south it dips 50° easterly. Below Walker's falls it stands nearly vertical. Our notes represent a feldspatho-hornblendic rock in horizontal plates immediately contiguous on the east, most likely lying upon the edges of this gneiss. If this proves correct, then the rest of the intermediate space to the crest of the range will be found occupied by the trachytic granite, the horizontal plates showing its beginning. If the horizontal position of the granites and felsites is to be regarded as produced by original deposition, then the elevation of the gneiss took place first; and this mass of mountains has been only slightly disturbed by elevating forces since that time.

The porphyritic area along the Ammonoosuc is probably a repetition of that near Echo lake, making a synclinal axis, just as in Benton, under Moosilauke. With this premise we can infer that the gneiss of Bethlehem was formed subsequently, and lies in a basin, with an east and west axis.

We cannot as yet locate the andalusite gneiss, save that it is newer than the porphyritic bands, as shown at Moosilauke.

There is one further suggestion in respect to relative ages. The Coös group of Littleton and Lisbon passes around the west end of the Bethlehem gneiss, showing that the latter existed before either the deposition or elevation of the former. This indicates that the whole of the White Mountain rocks are more ancient than the Coös and Quebec groups of the Connecticut valley.

Map Surveys and Levelling.

Some of the new material obtained for perfecting the map in 1870 was the following:

First, a new map of Connecticut river, from Massachusetts to Connecticut lake. Part of this was surveyed in 1825, with the expectation that a canal would be built along the river, as high as McIndoe's falls, in Bath. This very valuable map was presented to the survey by Dr. E. E. Phelps, of Windsor, Vt. It is superior to the county maps or the state map of Vermont, and is therefore the best one in existence. It represents things as they were in 1825; but there has been little change since that time except in the construction of new turnpikes and railroads.

Second, Messrs. Walling and Gray were employed late in the season to prepare a map of the river between Bath and Connecticut lake, from new surveys. This has been done carefully, and constitutes a very important addition to our materials for the final map. These same engineers also made careful odometer surveys of the Mt. Washington carriage road and the Fabyan turnpike, which are in our possession.

We commenced this year the preparation of a raised map of the state, for the museum, upon the scale of one mile to the inch. The table to serve as its foundation was placed in position, and nearly all the outside boundaries of the state drawn upon it. In 1871 Mr. Huntington drew contour lines for all of Coös county north of Shelburne and Lancaster, from which the north portion of the model has been constructed. At the same time I constructed a plan of the Franconia and Bethlehem mountains upon a much larger scale. This was designed to illustrate the theory of Prof. Agassiz respecting the northward transportation of boulders by a local glacier from the Franconia Mountains.

Additional work upon the model of the whole state was performed in 1873. It will not be best to complete this until the last item of facts concerning the topography of the state has been garnered in. The general facts upon which this is based will appear in the chapter upon topography.

The surveying necessary for the mapping of a part of the Ammonoosuc gold field, referred to heretofore, was completed in 1870. The last part of the work, setting the stakes for more than two square miles,

was performed under the direction of Prof. Quimby. The map shows the courses of all the valuable mineral veins existing upon the tract, as well as the remarkable windings and dislocations of the formations which are there exhibited. Not less than five hundred specimens were collected to illustrate this map.

A Trigonometrical Survey.

By an act passed in 1871, congress authorized the coast survey to expend a considerable sum of money in extending their triangulations into the interior, but only for those states where a geological survey is in progress. New Hampshire is the only one of the New England states which has so far received any benefit from this act, and the annual appropriation for this purpose has not been less than $2,000. The work has been placed in the hands of Professor E. T. Quimby, of Dartmouth college. He first occupied the stations established in 1869 for the benefit of the geological survey, so as to verify their accuracy. The work has been successfully carried on now for three seasons, and the latitudes and longitudes thus obtained are given in the chapter on topography.

Levelling along Connecticut River.

For the sake of a proper understanding of the surface geology of Connecticut river, it has been thought best to level from the Massachusetts line to Connecticut lake. The work was commenced in 1870 by Gyles Merrill, Jr., and S. Q. Robinson, of the class of 1872, C. S. D., Dartmouth college. They have levelled between the line and Walpole. Mr. Merrill was assisted also by his brother. The line from Bellows Falls to Windsor was levelled by Warren Upham in 1874. The work above Hanover was performed in 1871, under the direction of A. F. Reed, of Groton, Mass., assisted between Hanover and Lancaster by Dr. Nathan Barrows, of Meriden, and between Lancaster and Connecticut lake by Messrs. C. F. and F. A. Bradley, of the class of 1873, Dartmouth college. The connection between this survey and that of the P. & O. Railroad, at Dalton, was made by J. T. Woodbury in 1874.

In the report for 1871 there appears a long list of altitudes, including all that had been obtained by special surveys at that time. These are to be given more fully in a following chapter, with many additions and improvements.

Microscopical Researches.

In view of the importance of microscopical researches, not only in gaining knowledge of the mineral structure of rocks, but also of the "polishing powder" and other valuable minerals abundant in the state, we organized a new department of the survey in 1870, and obtained the assistance of Professor A. M. Edwards, of Newark, N. J., and Professor T. Egleston, of the School of Mines, Columbia college, New York. Professor Edwards has prepared an extensive report upon the organisms producing the lacustrine sedimentary deposits; and Professor Egleston has had charge of the cutting and description of rock sections.

Fossils in New Hampshire.

In October, 1870, while examining the limestones of Littleton, fossil corals were discovered. They were quite numerous, though obscure. Intelligence of the discovery was immediately telegraphed to the Dartmouth Scientific Association, who happened to be holding a meeting the same evening. It was announced to them that New Hampshire could no longer be called an *Azoic* state, since she had within her borders a coral reef of Silurian age.

Specimens were sent to E. Billings, F. G. S., paleontologist of the geological survey of Canada, who recognized the genera *Zaphrentis* and *Favosites*, and perceived the probable equivalency of these limestones with the Helderberg series of Memphremagog. The band of rock was at first supposed to be the same with the limestones of Dalton and Lancaster, and perhaps farther north. The fossils have been discovered in two localities, nearly two miles apart, upon what is thought to be the two sides of a synclinal axis. The limestone is underlaid by a quartzite and covered by a clay slate, the latter containing impressions of worm tracks. Though previously announced, this is believed to be the first authentic discovery of fossils in the solid rocks of New Hampshire.

No time could be devoted to this interesting department till 1873, when our labors were rewarded by the discovery of fossils characteristic of the Lower Helderberg. Mr. Huntington was so fortunate as to find, on Fitch hill, Littleton, specimens of brachiopods, a gasteropod, and large

crinoidal stems. Mr. Billings reports that the brachiopod is allied to the *Pentamerus Knightii* of the Lower Helderberg; and that the gasteropod is also like one in the same formation. The crinoidal fragments place this deposit in correlation with the noted bed at Bernardston, Mass., first described by my father in 1833. Geologists had supposed the latter bed to be of Devonian age, because the large crinoids seemed like those from the Corniferous beds in New York; but our discoveries serve to modify this conclusion. Considerable attention was devoted to the Helderberg deposits by us in 1873, and we have been enabled to derive most important generalizations respecting the structure of the state, second in importance only (though most would value them more highly) to the results of the White Mountain exploration. A lengthy sketch of the New Hampshire Helderberg rocks has been published in the *American Journal of Science* for April, 1874. Our next volume will treat the subject with all the detail required.

Quartzites in the Gneiss.

Hon. S. N. Bell, of Manchester, pointed out to me, before commencing the New Hampshire survey, the occurrence of interesting bands of quartzite in the southern part of the state. As soon as occasion offered, an examination of them was commenced. Mr. Bell often accompanied us on our expeditions, and for his own pleasure traced out thirty or forty miles of their extent. In 1871, in company with Mr. L. Holbrook, the limits of these bands were studied in Hillsborough, Merrimack, and Strafford counties. The results of our examination indicated that these two bands of quartzite traverse a tract of country, often in a serpentine course parallel to each other, eight or ten miles apart, from Temple to the north part of Strafford on one line, and from New Ipswich to the south part of Strafford on the other. Beyond this point the formations seem to be covered by the andalusite schists.

After passing a wide band of gneiss to the west of the Temple-Strafford range, we came to a belt of porphyritic gneiss, which seems to be the oldest formation in the state. In accordance with this view of the relative ages of the formations, we find similar rocks west from this central porphyritic gneiss. The studies commenced by G. A. Wheelock, of Keene, have brought to light two beds of the same quartzites in Keene

and Surry, separated by a wide band of gneiss from the central group. As the same rock appears in Grafton and Newport, fifty or sixty miles farther north, it is likely the same arrangement continues past the centre of the state; while the descriptions of my father, in the final report on the geology of Massachusetts, speak of a white quartzite having the same relations, midway through that commonwealth. Neither this, nor the band of porphyritic gneiss mentioned as passing nearly north and south from New Hampshire to Connecticut, on the meridian of Ware, was represented upon his map, as their importance was not appreciated.

In the report for 1872, a map of the southern part of New Hampshire was presented for the purpose of showing the course of these quartzite bands. The following statements were made respecting them:

Our map shows two nearly parallel ranges of quartzites,—the one extending from Allenstown to Mason, and the other from the same town to Temple. Diligent search has failed to reveal any traces of these bands beyond Allenstown, which surely belong to them. Inasmuch as the accompanying gneisses also terminate,—both those included between the ranges, and the crumpled granitic gneiss to the south-east,—and the mica schists beyond seem to have taken a northerly course, we conclude that the continuation of all those strata is concealed by the overlying blanket of mica schist. The map shows how completely these bands are interrupted by the newer schists. Nothing has yet been suggested to account for the termination of the quartzite bands in Temple and Mason. Further search may reveal them on the same line in Massachusetts.

The map shows these quartzites in Richmond, Keene, Surry, and Grafton, on the west side of the porphyritic range. We have not yet been able to trace them out in that part of the state. These ranges have been seen in Massachusetts, especially in New Salem. Their occurrence in two bands on both sides of the main anticlinal will furnish us the general clue to the stratigraphical structure of the gneiss, besides making plain the line of the granites and soapstone,—for there is a range of the latter mineral accompanying the Keene quartzites. It will be observed that the latter curve around the older porphyritic rocks of Swanzey.

It is almost exciting to follow the hills of this rock through the towns. They can be seen miles away, being as white as snow. The following are the most notable hills along its course: In East Concord, Oak hill; West Concord, Pine hill; on the Temple range, the foundations of the upper railroad bridge, and the Pinnacle in Hooksett; the hill of quartz quarried for the manufacture of glass in Lyndeborough, and a long ridge in Temple extending north-easterly from the village; on the Mason range, a high hill north-east from East Wilton; the north-east corner of Amherst; and Campbell hill in Hooksett. The ranges are 6.20 miles apart in New Boston and Bedford, narrowing to 3.12 in Hooksett, and 5 miles in Wilton. The most remote localities in

Temple and Mason are 6½ miles distant from each other. The Mason range does not curve to the west, as erroneously shown upon the map.

There are also ranges of quartzite in the mica schist group. The most extensive is in Raymond and Nottingham. Other outcrops are in Londonderry, Strafford, and Pittsfield. Those in Strafford were formerly regarded as the extension of the Temple and Mason ranges.

Museum.

Work has steadily progressed, during the continuance of the survey, upon the museum. Culver hall contains the specimens designed for the New Hampshire College of Agriculture and the Mechanic Arts; but the Concord collection still remains packed in boxes. Briefly, the special features of the museum are the following: A room about forty feet square is set apart for the illustration of the geology, mineralogy, paleontology, botany, and zoölogy of New Hampshire and Vermont. It is designed that every department shall be represented complete and entire. Only the collections of the survey have been presented by the state; but earnest efforts are put forth to secure the remainder by aid from friends of Dartmouth college. This institution being nearly the geographical centre of two states, it seems an appropriate place for this gathering of representations of their natural products and resources. The room now contains, first, and the most prominent feature, fourteen shelves, holding specimens collected along fourteen east and west lines across New Hampshire. Several of the section lines have been carried across to Lake Champlain. Behind each shelf is a colored profile of the route taken, drawn to an exact scale for heights and distances, each formation being distinguished from every other, the names of the groups and localities printed in large letters, numbers placed on the section to show the exact locality of every specimen, and the rocks appear in the immediate proximity of the figures on the wall. Lithological specimens, obtained between the section lines, are placed on the shelf in their proper relations, but not so as to be confounded with the others. There is also a series of large maps of the northern townships (and eventually there will be of all the rest), showing the topographical position of every lithological specimen in the collection. If possible, these will be reproduced for the report. Second, the room contains several sets of specimens, properly catalogued, to illustrate more

fully important areas. They are the White Mountain area, the Ammonoosuc gold field (including the Lyman map district), and the towns adjacent to Hanover. Third, a special collection of minerals; fourth, of fossils; fifth, of all economic materials, particularly the granites of New Hampshire, and the marbles and slates of Vermont; sixth, a special set to illustrate the distribution of boulders; seventh, numerous topographical models.

The college collections embrace, first, most of our birds, collected and presented by Prof. Henry Fairbanks, of St. Johnsbury, Vt.; second, one thousand species of New Hampshire insects, collected by C. P. Whitney, of Milford, and presented by Mr. Fairbanks; third, a few mammals, by the same; fourth, miscellaneous New Hampshire fish and reptiles; fifth, the plants of the White Mountains, collected by the survey, and the local flora of Hanover,—the latter gathered and presented to Dartmouth college by Miss Mary Hitchcock, of Hanover.

The state house collection ought to be equally comprehensive; but at present there are no rooms suitable for its accommodation.

The Mt. Washington Expedition.

The chief part of the report for 1870 is occupied by a sketch of the Mt. Washington expedition. The meteorological tables are given in full; and, side by side with them, observations from several other localities, taken at the same hours, for purposes of comparison. Mr. S. A. Nelson furnishes an admirable sketch of the meteorology of Mt. Washington, following the tables. His great skill in generalizing from facts will cause great regret that he was unable to prepare for this volume a sketch of the meteorology of the state.

Mr. Huntington's Labors.

We have been greatly favored, through most of our labors, by the perseverance of Mr. J. H. Huntington, principal assistant. He has entered thoroughly into the spirit of the work, and has fully identified himself with our explorations. Though having a special field of his own, he has always been ready to labor elsewhere whenever assistance was required. The following is a general outline of his work since the last mention of

him: In the early part of 1870, he traversed, on foot, the various mountain notches between the Saco, Pemigewasset, and Connecticut rivers, for the purpose of ascertaining their altitudes. Next he renewed the examination of the rocks of Coös county. Afterwards he joined our party in the White Mountain explorations. Later in the season he continued the exploration in Coös county and Bean's purchase. Later in the fall he devoted himself to the interests of the Mt. Washington meteorological expedition, attending to the completion of the arrangements for occupying the railroad depot as an observatory. The six months from the middle of November to the middle of May were spent by him mostly upon the summit, where he was the leader of the heroic party who risked their lives in behalf of science. When this task was completed, he resumed his work upon the geology of Coös county in 1871, being occupied until late in July with the compilation of his report upon the geology of Coös county. He then took the field and labored in the northern part of the state, also in Essex county, Vt.,—the latter without cost to the survey, though we receive the benefits of the exploration. In September he examined the formations near Jackson, Bartlett, Conway, Albany, etc., partly to carry on the search for labradorite rocks.

Essentially the same field was traversed by him in the summer of 1872. His researches in Albany will be found of special importance. In 1873, after the completion of the exploration in the northern part of the state, he commenced working in the gneissic district lying between the main range of porphyritic gneiss on the east, and the Connecticut valley Coös group. The sketch of the geology of this tract will be written by him as soon as possible. In the first volume, the chapter on meteorology has been prepared by him; also, topographical and scenographical contributions.

Miscellaneous.

Very much remains to be told of the history of our scientific explorations; but we fancy it will be more satisfactory to read the completed results than to learn how they have been effected. In the reports there has been a fine series of rock analyses by Profs. Seely and Blanpied; outline sketches of the subject-matter of this series of volumes; the progress of the microscopical department; additional meteorological

tables from Mt. Washington and Hanover; and a sketch of the geology of southern New Hampshire. The map illustrating it shows the following formations between the Exeter sienites and the Coös group, along Connecticut river, given in the supposed order of their age:

1. Porphyritic gneiss and granite.
2. Granitic gneiss.
3. White Mountain series, including andalusite gneiss, ordinary and imperfect gneiss, the so-called granite of Concord and Fitzwilliam, beds of soapstone and limestone.
4. Bands of quartzite.
5. Mica schist.
6. Andalusite slates or outliers of the Coös group. Of these the map distinguishes the porphyritic group, the quartzite bands, the mica schist, and the Coös outlier. The other gneiss, being yet known imperfectly, I will not attempt to divide.

The following remarks concerning the second group may be quoted, as this had not been distinguished from the adjacent groups before.

> There is decided evidence of a range of very ancient gneiss from Mason to Deerfield. It abounds in feldspar; the strata are very highly inclined and remarkably plicated. It is very granitic, so much so that but a slight additional metamorphic action would be needed to obliterate all the planes of stratification. This formation is probably repeated west of the quartzite ranges, and also in Cheshire and Sullivan counties. The character of the strata, and the superabundance of feldspar, readily distinguishes it from everything else.

Also, a few words about the "Concord granite," and the "mica schist" of Rockingham county.

> The "Concord granite" has been traced irregularly from Concord to Fitzwilliam. It will require more detailed examinations to enable us to say positively where this valuable band may be found. It seems to lie near the quartzite, say from a quarter to half a mile above it. Hence, if it exists as a range, it should be adjacent to all the quartzite bands, and its distribution can be determined readily in the manner suggested above. A section across these ranges near Manchester shows a similar granite inside both of them, while a protracted examination has failed to show the quartzite beyond the west part of Concord. This rock is not a proper granite. There is an arrangement of the particles of mica along parallel planes, which allows the rock to split readily. These we regard as strata. They are seen plainly in the inferior qualities of the stone, and farther south the celebrated "granite" of Pelham and Monson, Mass., shows the

strata perfectly. The latter appear to be identical with the Concord stone. Microscopic sections, when available for study, will add much to our knowledge of this variety of rock.

By scrutinizing the course of a band of rock closely packed with andalusite, it appears probable that the valuable soapstone of Francestown is continuous into Weare, as well as extending farther south-west. Outcrops have been found in four localities. The soapstone of Richmond resembles it also, and seems to be on the same course. Hon. M. A. Hodgdon, of Weare, has made an extensive excavation in this bed on Mt. Misery, which throws considerable light on its character.

Mica Schist. This formation covers a great area in Rockingham and Strafford counties. In general it is a simple compound of mica and quartz, resembling an argillaceous rock at times, and often showing the mica in irregular blotches. It everywhere contains beds of a very coarse granite. In the south part of Rockingham, in Barrington, Strafford, and elsewhere, the granite remains in ridges, while the schist has decomposed, thus making one believe granite to be the prevailing rock of the country, without careful search for the schist in the valleys.

The sienites of Exeter bound this group on the east. The Merrimack group seems to be distinct from it, though the two have been confounded together heretofore. This rock forms mountain masses in many towns. Such are the ridges between Hill's Corner and Shaker Village in Canterbury, the Pinnacle and Bean hill in Northfield, Catamount Mount in Pittsfield, Brush hill, McKays, Fort, and Nottingham mountains in Epsom, Saddleback Mount in Northwood, Devil's Den in Auburn, ridges in Farmington, etc. Narrow patches of mica schist occur resting in synclinal form on the gneiss west of the Merrimack river, but it is of no use to attempt to represent them at present.

Geological History of Winnipiseogee Lake.

The results of a tour in the vicinity of Winnipiseogee lake, in 1873, are given in a lengthy paper read before the American Association for the Advancement of Science, at Portland, in August. The greatest detail of the sketch relates to the supposed appearance of the lake country in the glacial and terrace periods, which need not be reproduced here. But I desire to state the phase of opinion expressed in this communication respecting the older groups. A large manuscript map illustrated to the geologists at the meeting the distribution of the formations deposited in the several periods enumerated. There are some new groups in this list.

We can trace no less than ten periods in the history of this lake basin:

1. Period of the deposition of the *Porphyritic Gneiss or Granite.* This is the oldest formation in the state. A range of it starts southerly from

Waterville, and proceeds south-westerly to Mt. Prospect, in Holderness. Thence it courses more southerly, proceeding to New Hampton centre village. In this vicinity it is developed more perfectly than in any other part of the state. At the village it makes a sharp turn eastward to Meredith Village; thence north-easterly nearly to Squam lake, in the extreme north-east part of Center Harbor. It then makes another sharp turn down both sides of Meredith, or North-west Cove, and appears also on the islands off Wiers and the north part of Gilford. It now rapidly diminishes in width, and finally disappears, coming up again in West Alton, and is last seen in the south part of Alton.

2. *Winnipiseogee Lake Gneiss formation.* This is a granitic gneiss filled with segregated veins, and has not yet been observed away from the vicinity of the lake. It does not appear upon any mountains, nor in bluffs, and has everywhere been greatly denuded, so that its ledges are inconspicuous. It joins the first named rock everywhere on the east, and covers it in Alton. The strata are highly inclined, and sometimes inverted.

3. *White Mountain Series.* This rock is often characterized by the presence of andalusite. It crops out in Gilford and Alton, and bounds the lake gneiss on the east, where the junction is not obscured by overlying formations.

4. The next great period may represent the time of the *elevation, and perhaps metamorphosis,* of the three groups already enumerated. We possess no decided evidence to show that these three groups are unconformable with one another. The presumption is that these groups belong to the Laurentian system;—they are certainly Eozoic.

5. *Eruption of the Granites of the Ossipee Mountains.* In a paper presented last year, a description was given of the rocks among the White Mountains, where it was stated that the upturned edges of the White Mountain series were covered first by a layer of coarse granite, and then by a "trachytic" or spotted granite. Both these varieties are found in the Ossipee mountains, and in a similar stratigraphical position.

6. *Deposition of Felsites or Compact Feldspars.* Enormous thicknesses of variously colored felsites cover the spotted granite of Ossipee, and form the summits of the pile of mountains. None of the ossipyte, a compound of labradorite and chrysolite, has yet been seen. These

granites and felsites together constitute a great series of formations, which, I suppose, are the equivalents of the Labrador system of Logan. He has not given the limits of his system; but I retain the name suggested by him for the group of granites and compact feldspars developed so finely in New Hampshire. There is an extensive mass of granite in Wolfeborough and New Durham, which may be connected with the Labrador system, but its relations have not yet been made out with certainty.

7. *Eruption of Sienite.* The Belknap Mountains, certain peaks in Alton, Diamond island, and probably Rattlesnake island in Winnipiseogee lake, and Red hill in Moultonborough and Sandwich, are composed of sienite of various textures, which seems to have been erupted after the deposition of the felsites. Its age is shown by the fact that it cuts the ossipyte in Waterville.

8. *Deposition of Mica Schists.* This formation is enormously developed in Strafford and Rockingham counties, touching the lake only at Alton Bay. It evidently covers all the formations thus far specified.

This is the last of the solid rocks in this area. There succeeds an enormous interval of time, of which we have no record in New Hampshire. The country must have been elevated, so that no deposits could be formed. The interval embraces the principal portion of the fossiliferous rocks.

9. *Glacier Period.* The phenomena of this age about the lake are striæ, embossed ledges, pot-holes, beds of clay, boulder drift, etc. The courses of the striæ usually agree with that of the valley, or from S. 25°–30 °E.

10. *The Terrace Period.* The presence of the ocean after the glacial period over the lake may possibly be indicated by the existence of the smelts in its waters, which are marine animals, possibly left behind when the salt water disappeared. The terraces seem to indicate that the water has stood successively at the heights of 100, 80, 55, 30, 23, 15, and 12 feet, but never any higher. There may have been egress for the waters in the direction of Squam lake, Gilford, and Alton.

Lengthy considerations are presented to show, by contrast to these small lake terraces, the fluviatile origin of the large banks of sand and gravel along the Merrimack river valley. The conclusions are of consid-

erable importance, and will be fully developed in that part of our report relating to surface geology.

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Fig. 6.—ICE FORMED ON MT. WASHINGTON WITH SOUTH WIND.

CHAPTER IV.

HISTORY OF EXPLORATIONS AMONG THE WHITE MOUNTAINS.

COMPILED BY WARREN UPHAM.

First Visits to Mt. Washington.

THE early history of the White Mountains may well be of interest to all who feel a pride in the beautiful scenery or in the material prosperity of this portion of our state. It is only a meagre record, however, that we are able to present. Even the name of the first adventurer who ascended these mountains was for some time uncertain. It was stated by Dr. Belknap, in the early editions of his history of New Hampshire, that Walter and Robert Neal were the first to climb the highest summit of the White Mountains, in 1631. This appears to be incorrect; and the error was noticed by the author in the edition of 1812. It is now considered settled that this credit is to be assigned to Darby Field, of Pascataquack (Portsmouth), who made the ascent, accompanied by two Indians, in June, 1642. An account of this has been preserved by Winthrop, from which it appears that "within 12 miles of the top was neither tree nor grass, but low savins, which they went upon the top of sometimes, but a continual ascent upon rocks, on a ridge between two valleys filled with snow, out of which came two branches of Saco river, which met at the foot of the hill, where was an Indian town of some 200 people. * * * By the way, among the rocks, there were two ponds,—one a blackish water, the other a reddish. The top of all was plain, about 60 feet square. On

the north side was such a precipice as they could scarce discern to the bottom. They had neither cloud nor wind on the top, and moderate heat. * * * About a month after he went again, with five or six in his company."* The appearance of the mountains is thus seen to have been the same two hundred years ago as now; but besides this description, Field brought back a glowing account of precious stones, &c., and even of sheets of "Muscovy glass," or mica, forty feet long! The enumeration of these wonders was probably employed to collect the party for his second expedition.

This inducement, also, says the historian, "caused divers others to travel thither, but they found nothing worth their pains." Of these are particularly mentioned Thomas Gorges and Mr. Vines, two magistrates of the province of Sir Ferdinando Gorges, who went about the end of August of the same year. "They went up Saco River in birch canoes, and that way they found it 90 miles to Pegwaggett, an Indian town; but by land it is but 60. Upon Saco River they found many thousand acres of rich meadow; but there are 10 falls, which hinder boats, &c. From the Indian town they went up hill (for the most part) about 30 miles in woody lands. They then went about 7 or 8 miles upon shattered rocks, without tree or grass, very steep all the way. At the top is a plain about 3 or 4 miles over, all shattered stones; and upon that is another rock or spire, about a mile in height, and about an acre of ground at the top. At the top of the plain arise four great rivers; each of them so much water at the first issue as would drive a mill: Connecticut River from two heads at the N. W. and S. W., which join in one about 60 miles off; Saco River on the S. E.; Amascoggin, which runs into Casco Bay, at the N. E.; and Kennebeck at the N. by E. The mountain runs E. and W. thirty miles, but the peak is above all the rest. They went and returned in 15 days."†

The route taken by Field, and probably by the other explorers also, lay from the Saco up Ellis river nearly to its source, and thence up the great ridge south-east of Mt. Washington, known as Boott's Spur. Tuckerman's ravine and Oakes's gulf, on either hand, are recognized as the "two valleys filled with snow." The summit of this spur brought

* Winthrop, N. E., by Savage, ii., p. 67. † Winthrop, ii. p. 89.

them to the broadest portion of the comparatively level tract at the southern base of Mt. Washington, the south-eastern part of which is the grassy expanse of some forty acres, known as Bigelow's Lawn. Between this and the summit they encountered the Lake of the Clouds, and smaller ponds, which no doubt furnished Gorges with a part of the sources of his rivers; and no one who has looked into the abyss somewhat absurdly denominated the "Gulf of Mexico," will wonder at its notice in the brief account of the first explorer. E. Tuckerman, in 1843, endeavored to trace the path of these earliest ascents, and was surprised with a view of Mt. Washington as a somewhat regular pyramid rising from an apparent plain, which is the way it was described by Gorges, and afterwards by Josselyn. Davis's bridle-path, opened in 1845, traversed the bold part of this ridge, and afforded the same view while it was in use.

The first mention of the White Mountains in print occurs in John Josselyn's "New England's Rarities Discovered," which was published in 1672, containing the earliest notice of the botany of the country. The materials for this and a subsequent work were collected by the author during two visits to New England, coming first in 1638 and remaining fifteen months, and again in 1663, remaining eight years. In his account of the mountains, he describes a pond upon the highest summit,—either from a defect of memory, or because he was satisfied with seeing them at a distance, without making the ascent, and mistook its position, as described by explorers. "Four-score miles," says Josselyn, "to the North-west of *Scarborow*, a Ridge of Mountains runs North-west and North-east an hundred leagues, known by the name of the *White Mountains*, upon which lieth snow all the year, and is a Landmark twenty miles off at Sea. It is rising ground from the seashore to these Hills, and they are inaccessible except by the Gullies which the dissolved Snow hath made. In these Gullies grow *Saven* bushes, which, being taken hold of, are a good help to the climbing discoverer. Upon the top of the highest of these Mountains is a large Level or Plain, of a day's journey over, whereon nothing grows but Moss. At the farther end of this Plain is another Hill called the *Sugarloaf*, to outward appearance a rude heap of massie stones piled one upon another; and you may, as you ascend, step from one stone to another as if you were going up a pair of stairs, but winding still about the Hill till you come to the top, which will require half a day's time,—

and yet it is not above a Mile,—where there is also a Level of about an Acre of ground, with a pond of clear water in the midst of it, which you may hear run down, but how it ascends is a mystery. From this rocky Hill you may see the whole country round about. It is far above the lower clouds; and from hence we beheld a Vapour (like a great Pillar) drawn up by the Sun Beams out of a great Lake or Pond into the air, where it was formed into a Cloud. The Country beyond these Hills Northward is daunting terrible, being full of rocky Hills as thick as Mole-hills in a Meadow, and cloathed with infinite thick Woods."* In his "Voyages," published a year or two later, Josselyn corrects what he says of the snow's lying the whole year upon the mountains, by excepting the month of August.†

The "Voyages" contain an account of the Indian traditions which clustered about our highest mountains. "Ask them," says Josselyn, "whither they go when they dye, they will tell you, pointing with their finger to Heaven, beyond the White Mountains; and do hint at Noah's Floud, as may be conceived by a story they have received from Father to Son, time out of mind, that a great while agon their Countrey was drowned, and all the People and other Creatures in it, only one *Powaw* and his *Webb*, foreseeing the Floud, fled to the White Mountains, carrying a hare along with them, and so escaped. After a while, the Powaw sent the Hare away, who not returning, emboldened thereby, they descended, and lived many years after and had many children, from whom the Countrie was again filled with Indians."‡ None of the traditions of the native tribes appear to have been so widespread as that of a flood; and many notices might be cited similar to this of the White Mountains. Catlin describes a ceremony referring to this which he witnessed among the Mandans, on the upper Missouri river, where the only survivor was represented as white.

The next mention of explorations among the White Mountains is on April 29, 1725, when "a ranging company ascended the highest mountain on the N. W. part,"—probably the first ascent from this side. As was to be expected, they found the snow deep and the Alpine ponds frozen.‖ Another ranging party being "in the neighborhood of the White

* N. E. Rarities Disc., p. 3. † Josselyn's Voyages, p. 55. ‡ Ibid, p. 135. ‖ Belknap, N. H., iii., p. 35.

Mountains, on a warm day in the Month of March, in 1746, were alarmed with a repeated noise, which they supposed to be the firing of guns. On further search, they found it to be caused by rocks falling from the south side of a steep mountain."* This is the first notice that we find of the mighty force that has left its furrows and scars all through the mountains, and which caused to be written the saddest page in their history.

Discovery of the White Mountain Notch.

It is supposed that the Indians were aware of the central pass through the White Mountains, and took their captives through it to Canada; but its existence was unknown to the English at the time of the first settlements of the Coös country. The value of these lands was thus very much diminished on account of the wide circuit which must be made either to east or west to communicate with the seaboard, so that it became a matter of inquiry to the authorities of the state how a way should be opened through this almost impassable chain. Its discovery was made in 1771 by one Timothy Nash, a pioneer hunter who had established himself in this solitary region. Climbing a tree on Cherry mountain in search of a moose, he discovered, as he thought, the wished-for pass. Steering for the opening, he soon struck the Saco river, a mere brook, and, following down, stopped at what is now known as the gate of the notch. Here the sharp rocks came so near together as to prevent his following the stream; but, seeing that by a reasonable expenditure a road could be opened at the point, he scaled the cliffs and continued on to Portsmouth. Here he made known his discovery to Governor Wentworth. The wary governor, to test the practicability of the pass, informed Nash that if he would bring him a horse down through the gorge from Lancaster, he would grant him the tract of land now known as Nash and Sawyer's location. To accomplish this, Nash admitted a fellow hunter, Benjamin Sawyer, to a share in his trade. By means of ropes they succeeded in getting the horse over the projecting cliff and down the rugged pathway of the mountain torrent, and brought him to the governor. When they saw the horse safely lowered on the south side of the last projection, it is said that Sawyer, draining the last

*Belknap, N. H., iii, p. 27.

drop of rum from his junk bottle, and breaking it on the rock, called it Sawyer's rock, by which name it has ever since been known. A road was soon opened by the proprietors of lands in the upper Coös, and settlers began to make their way into the immediate vicinity of the mountains. Jefferson, Whitefield, Littleton, and Franconia were first settled within two or three years after this date. A road was also commenced through the eastern, or Pinkham notch, in 1774, and Shelburne, which included Gorham, received its first inhabitants in the following year.

The earliest articles of commerce taken through the notch have not escaped mention. They appear to have been a barrel of tobacco, raised at Lancaster, which was carried to Portsmouth, and a barrel of rum which a company in Portland offered to any one who should succeed in taking it through the pass. This was done by Captain Rosebrook, with some assistance, though it was nearly empty, we are informed, "through the politeness of those who helped to manage the affair." The difficulty of communication was often the occasion of more serious want, and it was no rare thing to suffer from scarcity of provisions. In 1800, the inhabitants of Bethlehem were obliged to leave their occupations, go into the woods, and cut and burn timber enough for a load of potash, with which to procure provisions after a journey of one hundred and seventy miles. The tenth turnpike of New Hampshire was incorporated in 1803, to extend from the west line of Bartlett, through the White Mountain notch, a distance of twenty miles. The original cost of the road was forty thousand dollars, and the expense of repairs was large; but it proved a profitable investment. Strings of teams of half a mile in length were sometimes seen winding through Conway on their route to Portland, the great market at that time for all northern New Hampshire.

Visits of Scientific Parties.

Mt. Washington was ascended in July, 1784, "with a view to make particular observations on the several phenomena which might occur," the party consisting of the Rev. Manasseh Cutler, of Ipswich, Mass., a zealous member of the American Academy of Arts and Sciences, the Rev. Daniel Little, of Kennebunk, Me., also a member of the Academy, and Col. John Whipple, of Jefferson (then Dartmouth), together with others to the number of seven in all. They are said to have been "the

subject of much speculation" as they passed through Eaton and Conway. Dr. Belknap, the early historian of the state, and Dr. Fisher, of Beverly, Mass., were of this party, but neither of them succeeded in reaching the summit. Dr. Fisher remained at the notch "to collect birds, and other animal and vegetable productions." The objects of the expedition were but partially attained. It happened unfortunately that thick clouds covered the mountains nearly the whole time, so that the instruments, which they had carried up with much labor, were rendered useless. They made some unsatisfactory barometrical observations, but were unable to test them in an attempted geometrical measurement from the base. The barometer had suffered so much agitation that an allowance was necessary, and the altitude was computed in round numbers at 5,500 feet above the meadow in the valley below, and nearly 10,000 feet above the level of the sea. This was no greater altitude than appears to have been generally assigned to these mountains. Dr. Belknap, in 1792, gave his opinion that these figures were too small, predicting "that whenever the mountain can be measured with the requisite precision, it will be found to exceed ten thousand feet, of perpendicular altitude, above the level of the ocean."*

The plants of the upper region were now described for the first time, but only in a general way. The following extract from a manuscript of Dr. Cutler, which is quoted by Belknap, points out the more prominent botanical features, as seen by the first scientific party: "There is evidently the appearance of three zones,—1, the woods; 2, the bald, mossy part; 3, the part above vegetation. The same appearance has been observed on the Alps and all other high mountains. I recollect no grass on the plain. The spaces between the rocks in the second zone and on the plain are filled with spruce and fir, which perhaps have been growing ever since the creation, and yet many of them have not attained a greater height than three or four inches; but their spreading tops are so thick and strong as to support the weight of a man without yielding in the smallest degree;—the snows and winds keeping the surface even with the general surface of the rocks. In many places on the sides we could get glades of this growth some rods in extent, when we could, by sitting down on our

* Belknap, N. H. iii, p. 38.

feet, slide the whole length. The tops of the growth of wood were so thick and firm as to bear us currently a considerable distance before we arrived at the utmost boundaries, which were almost as well defined as the water on the shore of a pond. The tops of the wood had the appearance of having been shorn off, exhibiting a smooth surface from their upper limits for a great distance down the mountain." "On the uppermost rock" the letters "N. H." were engraved; and a plate of lead bearing the names of the party was deposited under a stone.

The route by which Cutler and his party reached the mountain is probably indicated by the stream which bears his name in Bigelow's narrative. "In less than half a mile southward from this fountain,"—that is, of Ellis river, at the height of land between the Saco and the Androscoggin, in Pinkham woods,—"a large stream, which runs down the highest of the White Mountains, falls into Ellis river; and, in about the same distance from this, another falls from the same mountain. The former of these streams is Cutler's river, the latter New river." This name is said to have been applied to the stream at Dr. Cutler's express wish.

A "Second Scientific Visit" was made in 1804 by Dr. Cutler, who was accompanied by W. D. Peck, afterwards professor of natural history at Cambridge, Mass. Barometrical observations made on this occasion, and computed by Mr. Bowditch, gave to Mt. Washington an elevation of 7,055 feet above the sea. A collection of the Alpine plants was made by Dr. Peck, and was afterwards seen by Mr. Pursh, in whose "Flora of North America," printed in 1814, many of the most interesting species were described. Naturalists soon began to give special attention to the peculiar Arctic flora and fauna of these mountains. A quite complete enumeration and description of the phænogamous plants, together with a statement of much concerning their mineralogy and zoölogy appeared in Dr. Bigelow's "Account of the White Mountains of New Hampshire," published in 1816, from explorations made during the same season. Dr. Francis Boott, Mr. Francis C. Gray, and the venerable Chief Justice Shaw were members of this party. The barometrical observations which they obtained gave 6,225 feet above the sea. This visit was made in June; and Dr. Boott made a second visit the succeeding month, adding a considerable number of species to the botanical collections. The ascent was from the eastern pass, following Cutler's river. In 1819, Abel Crawford opened

a footway to Mt. Washington, following the south-western ridge. This, and the new road made two years later by Ethan Allen Crawford along the Ammonoosuc, subsequently became the more common ways of ascending the mountains. Botanists were gainers by this change, especially those whose work was carried on without camping out, as these routes enabled them to examine the finest localities for Alpine plants while on their way to the summit. An account of the expedition of 1816 appeared in the *New England Journal of Medicine and Surgery* for November of the same year.

MAPS, SURVEYS, AND NAMES.

The first and only map of New Hampshire issued under the direction of the state authorities, was that of Philip Carrigain, published in 1816. The author's name is still preserved at the White Mountains, as that of the noblest of the peaks upon the east branch of the Pemigewasset,—too distant, however, from settlements to be often visited by tourists. This map notices that recent barometrical calculations give 7,162 feet above the sea as the height of the White Mountains; and states that, being below the line of perpetual congelation, which must be 7,200 feet lower than in Europe on the same parallel, they cannot exceed 7,800 feet. The author then somewhat incorrectly adds,—"After every abridgment of the heretofore exaggerated estimates of their altitude, it will be found doubly to exceed that of any mountain in the United States other than those of New Hampshire." The Franconia and Mt. Washington ranges, with intervening ranges and peaks, are laid down on this map; but no names are applied to individual summits throughout this central area of the White Mountains, with the exception of Lafayette, which is called "Great Haystack." The prominent mountains which stand on guard just outside this area, however, were already distinguished by the same names as now. We find "Pigwacket Mt., formerly Kiarsarge;" "Corway Peak Mt." (Chocorua); also, "Corway" pond and river; and, on the west, Kinsman's Mt. and "Moosehillock" Mt. The latter is in the town of "Coventry," changed to Benton in 1840. Albany, Woodstock, Carroll, Randolph, and Jackson are designated by the names *Burton, Peeling, Breton Woods, Durand, and Adams*. The name of "Merrimack River, or Pemigewasset Br.," is applied to that stream above Franklin; while the

East Branch is marked "Merrimack R." The names *Hancock Br.* and "*Moosehillock*" *Br.*, and the old form *Ammariscoggin*, are also found on this map. In his short notice of the productions and natural features of the state, the author remarks, referring to its lake and mountain scenery, "It may be called the Switzerland of America,"—a term which has been generally adopted in descriptions of New Hampshire.

The first carefully prepared map of the White Mountains was published by Prof. G. P. Bond, of Cambridge, Mass., in 1853, from original triangulation. The history of the efforts of the geological survey to secure more perfect maps of this region, with the result of these labors, is given in another part of this work.

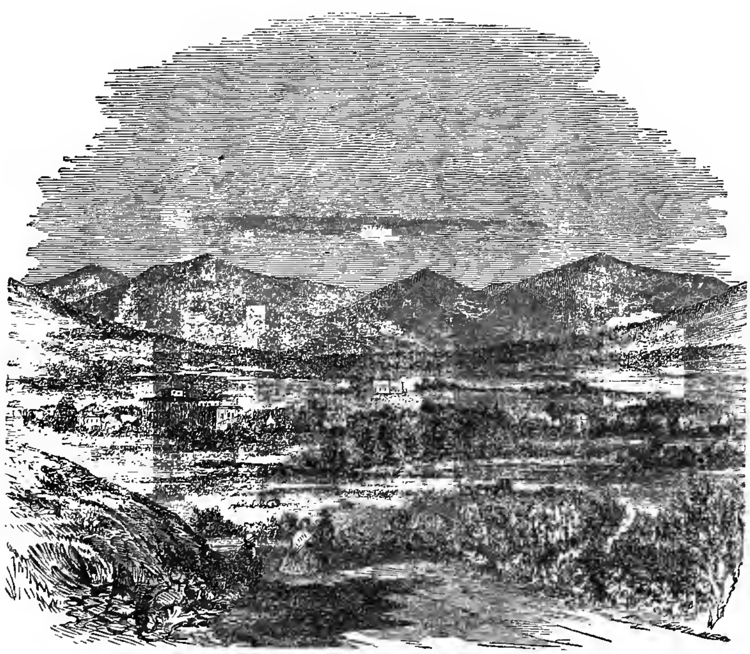


Fig. 7.—LANCASTER AND THE WHITE MOUNTAINS.

Considerable interest appears to have been awakened as to the altitude of these mountains, on account of the conflicting results of barometrical measurements; and we find that in July, 1820, a party of engineers and others from Lancaster visited the whole range between the notch and Mt. Madison, and, on a second visit, measured the altitudes with a spirit

level. The first party consisted of Adino N. Brackett, John W. Weeks, Gen. John Wilson, Charles J. Stuart, Noyes S. Dennison, and Samuel A. Pearson, of Lancaster, with Philip Carrigain and E. A. Crawford, the latter acting as pilot and baggage-carrier. This party gave names to Mts. Pleasant, Franklin, Monroe, Jefferson, Adams, and Madison. They called the Lake of the Clouds "Blue pond;" and the locality since named after Bigelow was by them called "Carrigain's lawn." The dead, gnarled trees, which are especially conspicuous on Moosilauke and common on all the mountains, received special notice. They were called by some members of the party *buck's horns,* and by others *bleached bones.* The cause of the death of these trees they supposed to have been the cold seasons which prevailed from 1812 to 1816, saying,—"It can hardly be doubted that during the whole of the year 1816 these trees continued frozen." This was the year long remembered as the "year without a summer." About a month after this visit, Weeks, Stuart, and Brackett, accompanied by Richard Eastman, spent seven days in levelling to the tops of all these mountains from Lancaster, encamping on them four nights;—that of August 31st on the summit of Mt. Washington. They must have been the first party who ever spent the night upon the summit. They made Mt. Washington 6,428 feet above the sea, or 5,850 feet above the river at Lancaster. An interesting account of these visits is found in the "New Hampshire Historical Collections" for 1823. During the year following these visits, Capt. Partridge again computed the height of Mt. Washington from barometrical observations, giving 6,234 feet. The observations of Dr. C. T. Jackson, in 1840, were quite accurate for the difference in height between Mt. Washington and the notch. Correcting the error for the height of the notch, his figures would stand 6,303, instead of 6,228, only ten feet in excess of the correct height. Prof. Arnold Guyot, in 1851, from barometrical observations, gives the figures of 6,291 feet. In his memoir of the "Appalachian Mountain System," published in 1861, he has altered these figures to 6,288. In 1853, Capt. T. J. Cram levelled to the summit of Mt. Washington, under the direction of the United States Coast Survey, and reported its height to be 6,293 feet, which may be assumed to be the true altitude.

The Indians are said to have been restrained by awe and fear from climbing to the summits of these mountains. Their traditions repre-

sented that here was the residence of the Great Spirit, who, with a motion of the hand, could raise a storm and destroy the daring adventurer who presumed to approach his abode. They never felt, amid the sublimity and awfulness of the mountains, that sense of ownership and appropriation which was inspired by rivers and lakes, with their calmer beauty and life-sustaining productiveness. Thus, while solitary mountains throughout the state, like nearly all the rivers, still preserve the names of their ancient baptism, always the last memorial of a departed race, the central portion of the White Mountains is wholly English in name and associations. We do not know that the Indians distinguished them by any other than a collective name. This, according to Dr. Belknap, was *Agiocochook* in one dialect, and in another *Waumbekket-Methna*, signifying *Mountains with snowy foreheads*. The English name *White Mountains* we meet in the earliest account of them that was published. It is not improbable that this name was applied to them while as yet they were only known to adventurous mariners in their exploring voyages along the coast.

It is impossible to ascertain with certainty who first proposed to call the highest of these summits Mt. Washington. Dr. Belknap, in 1792, says of it,—"it has lately been distinguished by the name of Mount Washington." He quotes from the manuscript of Dr. Cutler, in another place, the account of the zones of vegetation, where mention is made of "Mount Washington" as if it were well known. As his visit was made in 1784, it is not unlikely that the name was proposed soon after the close of the revolutionary war, probably by Dr. Cutler's party. Of other prominent peaks, besides those named by the party of 1820, Mt. Clinton received its name from some undiscoverable source, certainly before 1837. Mts. Clay and Jackson were named by Mr. Oakes. This gentleman was with Prof. Tuckerman, and sent up his guide, Amasa Allen, to build a fire on the top of the south spur of Clinton; and thus, with a fiery baptism, the mountain was christened Jackson. Mt. Willard was named from Mr. Sidney Willard, of Boston; and it is probable that the name of Mt. Webster was proposed by Mr. Willard for the peak known to earlier visitors as Notch mountain. Lower down the Saco, Mts. Crawford and Resolution, as well as the Giant's stairs, received names from Dr. S. A. Bemis. The names of Tuckerman's ravine, Oakes's gulf, and Bigelow's

lawn were given, in honor of three eminent botanists who had particularly distinguished themselves in the study of the White Mountain flora, to three fine localities of plants as well as marked topographical features. It is difficult to ascertain the origin of many of the names of natural objects about the mountains. Dr. Bemis has perhaps applied more appellations than any other person to these features. Other names have been given by chance visitors, and preserved by usage among guides.

No Indian legends remain about the mountains, and but few localities have a particular history. There is one cascade, however, about a quarter of a mile from the former residence of old Abel Crawford, which is more distinguished by the sad story associated with it, than by the picturesqueness of the crags through which it hurries for the last mile of its descent. It is called "Nancy's brook." Here, late in the autumn of 1788, a young woman, who had lived with a family in Jefferson, was found frozen to death. She was engaged to be married to a man who was employed in the same family where she served, and had entrusted to him all her earnings, with the understanding that in a few days they should leave for Portsmouth to be married there. During her temporary absence at Lancaster, nine miles distant, the man started with his employer for Portsmouth, leaving no explanation or message for her. She learned the fact of her desertion on the same day, and at once walked back to Jefferson, tied up a small bundle of clothing, and, in spite of all warnings and entreaties, set out on foot to overtake them. The distance to the notch was thirty miles, with no settlement on the way, the only road being a hunter's path marked by spotted trees. It had been snowing, but she pressed on over this road through the night, in the hope of overtaking her lover at the camp in the notch before the party should start in the morning. She reached it soon after they had left, and it appeared to those who, alarmed for her safety, had followed on from Jefferson to overtake her, that she had tried in vain to rekindle the fire in the lonely camp. Failing in this, she had hurried on, climbing the wild pass of the notch, and following the track of the Saco towards Conway. Several miles of the roughest part of the way she travelled thus, often fording the river. But her strength was spent by two or three hours of such toil; and she was found by the party in pursuit of her, chilled and stiff in the snow, at the

foot of an aged tree near "Nancy's bridge," not many hours after she had ceased to breathe.

Early Settlements.

President Dwight, of Yale college, visited the notch in 1797, and again in 1803, and has left in his "Travels" an appreciative description of the White Mountain scenery, besides some account of the early settlers of this region. The two prominent names are those of Eleazer Rosebrook and Abel Crawford. Mr. Rosebrook was a pioneer from Grafton, Mass., whence he removed to Lancaster about 1772; he finally settled at Monadnock, now Colebrook. Here he was fully thirty miles from any inhabitant, with no path to his cabin excepting blazed trees. During the revolutionary war he removed to Guildhall, Vt., in order to place his family in the neighborhood of settlements, being absent from them most of the time in the military service of the frontier. In 1792, he sold his fine farm on the Connecticut, and once more sought the wilderness,—removing, in the depth of winter, to Nash & Sawyer's location. Here he soon built a large two-story house, at the base of what was known as the Giant's grave, occupying nearly the same site as the present Fabyan house. He also built a saw-mill and grist-mill, and large barns, stables,

Fig. 8.—GIANT'S GRAVE.

and sheds. He had hardly become comfortably situated, however, when a cancer broke out on his lip, and after a few years of intense suffering, which was patiently borne, he died September 27th, 1817. "In all respects Mr. Rosebrook was a remarkable man. He loved the rugged scenes of pioneer life, and was never more in his element than while scaling the mountain, or trapping the wolf or bear. There are men enough who prefer the city, and cling fondly around their native village; but he could never endure the restraints connected with our larger settlements,—the restraints of artificial life; but freely, his arms and broad chest all bare, he must breathe the strong, pure air, as it came rushing along through these mountain gorges."

Abel Crawford, who married Capt. Rosebrook's daughter, and who is remembered as the "patriarch of the mountains," also came from Guildhall a few years later, locating himself twelve miles farther south, near the site of the present Mt. Crawford house. In 1840, at the age of seventy-five, he made the first horseback ascent to the top of Mt. Washington. Dr. C. T. Jackson, state geologist, was a member of the same party. Mr. Crawford died at the advanced age of eighty-five. For sixty years he had been acquainted with this region, and had seen the gradual process of civilization applied to the wilderness from upper Bartlett to Bethlehem. So long had he been accustomed to travellers during the summer months, that he felt he could not die without seeing them arrive once more. "He used to sit, in the warm spring days, supported by his daughter, his snow-white hair falling to his shoulders, waiting for the first ripple of that large tide which he had seen increasing in volume for twenty years. Not long after the stages began to carry their summer freight by his door, he passed away."

His son, Ethan Allen Crawford, succeeded to the estate of Capt. Rosebrook; but the ample buildings which the latter had reared were soon after burned to the ground. For many years the Crawfords were the only ones to entertain strangers at the mountains. All the bridle-paths on the west side were cut by them, the first of which, made for a foot-path in 1821, extended from the Rosebrook place, nearly seven miles, to the foot of Mt. Washington, following the Ammonoosuc river. It was afterwards known as "Fabyan's road." It was in this year that ladies first climbed to the summit. They were three in number,—sisters,—the Misses Austin, of

Portsmouth. With a firm determination to obtain a fine prospect, they remained four days near the top in a small stone cabin, until the weather became propitious. With the beginning of the present century, visitors to the White Mountains increased in number. In 1819, the number averaged ten or twelve annually; and the pioneer settlers began to provide means for their accommodation. Abel Crawford and his sons were the efficient guides of the early visitors; and many traditions are still current of their skill and strength, both as guides and hunters. They were all of the largest stature; and Ethan Allen, known as the "giant of the mountains," was nearly seven feet in height. With additional facilities, the number of visitors gradually increased, so that in 1858 it was estimated that five thousand annually ascended the various bridle-paths. In 1870, the number was estimated at seven thousand, of whom five thousand registered their names at the Tip-top house.

Of all the adventurous lives which have been passed among the shadows of these mountains, perhaps none exceeds, in thrilling interest and remarkable contrasts, that of Ethan Allen Crawford, whom we have already had occasion several times to mention. A considerable "History of the White Mountains," with his experiences and reminiscences, has been left us by his own hand. Many of the wisest and most distinguished of the country were entertained under his rude roof, who gratefully remembered his hospitality and his faithful service in guiding them to the great ridge. He would come home from a bear-fight to find in his house, perhaps, "a member of congress, Daniel Webster," who desired his assistance on foot to the summit of Mt. Washington. Ethan says that they went up "without meeting anything worthy of note, more than was common for me to find; *but to him things appeared interesting.* And when we arrived there he addressed himself in this way, saying,—'Mt. Washington, I have come a long distance, and have toiled hard to arrive at your summit, and now you give me a cold reception. I am extremely sorry that I shall not have time enough to view this grand prospect which lies before me; and nothing prevents but the uncomfortable atmosphere in which you reside.'" The snow from a sudden squall froze upon them as they descended. The statesman had evidently become interested in his guide, for Ethan adds that "the next morning, after paying his bill, he made me a handsome present of twenty dollars."

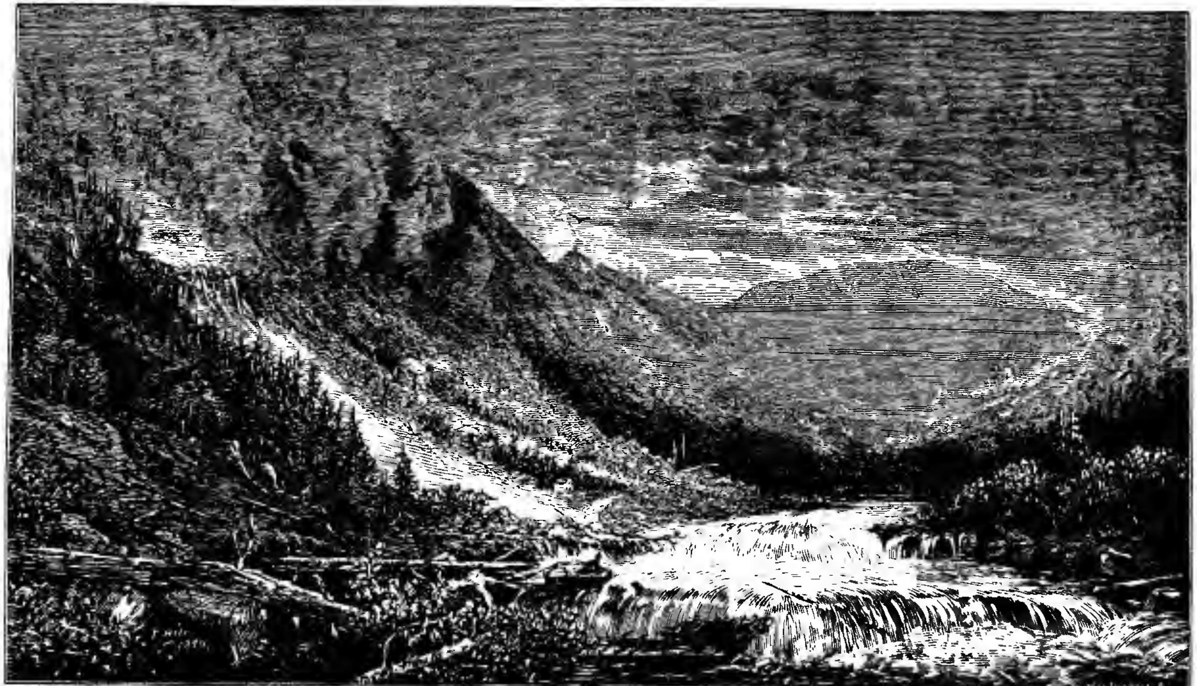
The fire which destroyed his buildings left him heavily oppressed by debts, a burden which he was never able to throw off. His crops were swept away, and his meadows filled with sand by freshets. Other forms of adversity, too, beset him. Before middle life, his own powerful frame was so shaken by disease and pain that a flash of lightning, he would sometimes say, seemed to run from his spine to the ends of his hair. But the example of his wife taught him how to meet calamity and distress without despair and repining. He was put in jail at last, in Lancaster, for debt. She wrote a pleading letter to his chief creditor to release him, but without effect. "This," says Ethan, "forced me, in the jail, to reflect on human nature, and it overcame me so that I was obliged to call for the advice of physicians and a nurse." Broken in health, oppressed by pecuniary burdens, and with shattered spirits, he left the plateau at the base of Mt. Washington for a more pleasant home in Vermont. But he experienced hard fortune there, too, and returned to die within sight of the range, an old man, before he had reached the age of fifty-six years.

"Since the breaking up of his home at the Giant's grave," says T. Starr King, "the mountains have heard no music which they have echöed so heartily as the windings of his horn, and the roar of the cannon which he used to load to the muzzle, that his guests might hear a park of artillery reply. Few men that have ever visited the mountains have done more faithful work, or borne so much adversity and suffering. The cutting of his heel-cord with an axe, when he was chopping out the first path up Mt. Washington, was a type of the result to himself of his years of toil in the wilderness; and his own quaint reflection on that wound, which inflicted lameness upon him for months, is the most appropriate inscription,—after the simple words, 'an honest man,'—that could be reared over his grave:—'So it is that men suffer various ways in advancing civilization; and, through God, mankind are indebted to the labors of men in many different spheres of life.'"

At about the same time with the settlement of the Crawfords, a tract of land three miles below the mouth of the notch was first improved by a Mr. Davies; this was the farm afterwards occupied by Mr. Willey. In describing his second visit to this place, President Dwight has preserved a record of one of the great fires which have devastated the mountains of the notch. "When we entered upon this

farm in 1803, a fire, which not long before had been kindled in its skirts, had spread over an extensive region of the mountains on the north-east, and consumed all the vegetation, and most of the soil, which was chiefly vegetable mould, in its progress. The whole tract, from the base to the summit, was alternately white and dappled; while the melancholy remains of half-burnt trees, which hung here and there on the immense steeps, finished the picture of barrenness and death." Old Mr. Crawford is said to have been accustomed, about the year 1845, to refer to the great fire which reduced Mt. Crawford to its present condition, as occurring some thirty years before. A similar fire, occurring seventy or eighty years ago and burning for several weeks, is said to have produced the barren aspect of Mt. Monadnock, in the south-west part of the state. The time may arrive when the record of these irreparable mischiefs, destroying the vitality of the mountains and leaving only naked and desolate rocks, shall possess a mournful value.

Several years after this visit by Dwight, the house was built upon the Davies farm by a Mr. Henry Hill, which is yet standing, being familiarly known as the "Willey house," and interesting as a monument of the fearful tragedy which occurred here August 28th, 1826. In the autumn of 1825, Mr. Samuel Willey with his family moved into this house. In the June following, a slide occurred near them upon the mountain, since called "Mt. Willey," which rose at a threatening angle some two thousand feet, with its base close behind the house. This, which was the warning of the impending disaster, at first greatly alarmed the family, and they resolved to remove from the notch. But Mr. Willey, on reflection, felt confident that such an event was not likely to occur again, and was satisfied with building a place of shelter to which the family might fly, if another slide seemed to threaten their home. Later in the summer there was a long hot drought, by which the earth had been dried to an unusual depth, thus preparing the surface to be operated on more powerfully by a sudden and copious rain. This began to fall on Sunday, the 27th of August; and on the next day the storm was very severe, especially in the vicinity of the mountains. On the morning of Tuesday the sun rose in a cloudless sky, and the air was remarkably transparent. During the preceding night the Saco had risen twenty-four feet, and swept the whole interval between the notch and Conway. The storm had wrought with



THE MORNING AFTER THE WILLEY SLIDE

a terrible effect upon the sides of the Mt. Washington range. The whole line was devastated by land-slides. A party ascending the Ammonoosuc soon after, counted thirty along their path, some of which ravaged more than a hundred acres of the wilderness. On the declivities towards North Conway, it was thought that this one storm dismantled more of the great range than all the rains of a hundred years before. As soon as the fate of the Willey family became known, relatives at Conway, and many neighbors, hurried to the notch. An immense slide had come down the mountain directly towards the house, but had been divided by a huge boulder thirty feet high, in the rear of the buildings, uniting again in front. A portion of the stable had been swept away. The doors of the house were all open, and beds and clothing showed that the family had hurriedly left. They had probably fled from the only place of safety at just the moment to be overwhelmed in the terrible pathway of the

Fig. 9.—THE WILLEY SLIDE AND MONUMENT.

slide. The whole family,—Mr. Willey, his wife, and five children, together with two hired men,—had perished. Search for the bodies was at once commenced. The first found was that of one of the hired men, David Allen, a man of powerful frame and remarkable strength. He was found

near the top of a pile of earth and shattered timbers, with "hands clenched, and full of broken sticks and small limbs of trees." The bodies of Mrs. Willey and her husband were also discovered, but so crushed as to be hardly recognized. Rude coffins were prepared, and the next day, Friday, about sunset, they were buried in a single wide grave, and the simple burial service was offered, amid the solemnity and desolation of the mountains. The bodies of two of the children and the other hired man, David Nickerson, were found a day or two after, and also buried, but the remaining three children were never discovered.

Hotels, and Modes of Ascent.

Soon after the completion of the rude bridle-path in 1821, by Ethan Crawford, it was perceived that a house of some sort was needed upon the summit, where visitors could spend the night. Hence Mr. Crawford constructed a stone cabin near the top of Mt. Washington, by the side of a spring. In this was spread an abundance of soft moss for beds; and thus travellers were enabled to view the setting and rising of the sun. After a while a small stove was brought up, with an iron chest and a long roll of sheet lead. The chest was the receptacle for the camping blankets, and the lead was the register for visitors. Every winter this house was seriously damaged. The roof would be blown away, and the stones fall down from the walls,—the chest and stove remaining, sadly rusted. Finally, at the great storm of August 28, 1826, when the Willey family were destroyed, this cabin, with the iron chest and the blankets, was swept down the steep slope and lost. A party had taken possession for the night, but were terrified by the violence of the storm, and had hastened down the mountain just in time to save their lives.

In 1852, J. S. Hall and L. M. Rosebrook built the Summit house on the very top of the mountain. It is twenty-four by sixty-four feet, quite low, with very thick walls of stone firmly cemented together, and bolted down to the solid rock. Over the roof are four strong cables. This house has now stood for more than twenty years.

A year later the Tip-top house was built by Samuel F. Spalding & Co. It is twenty-eight by eighty-four feet, and was built in the same substantial manner as the other. These two houses were originally under different management, but after 1859 they were both leased by the


NOTCH FROM CRAWFORD HOUSE

proprietor of the Alpine house, in Gorham; and many thousand people remember their stay here as one of the novel experiences of the mountain tour. Within two years the Mt. Washington house,—a new and very commodious hotel building, provided with all the modern improvements, and quite in contrast with the former accommodations,—has been erected on the summit. It was first opened to the public in the summer of 1873, averaging about one hundred guests daily. J. E. Lyon and Walter Aiken are understood to be the proprietors; and the manager is Capt. J. W. Dodge.

There has been a controversy concerning the ownership of the land upon the summit of Mt. Washington. In the early legislation of New Hampshire respecting the unoccupied lands of the state, little attention was paid to exact boundaries; consequently, each of the two parties claiming the summit had reason to believe it to be included within their limits. Mr. Bellows, of Exeter, owns the land upon the east side, and was the party in possession till about fifteen years ago, when his tenants were ejected by the sheriff acting for Coe & Pingree, of Bangor, Me., and Salem, Mass. Probably more than twenty-five thousand dollars was spent in contesting the matter of ownership before the courts, which has since been settled through purchase, by Coe & Pingree, of all the rights and claims of the former occupant.

The first good public house for summer visitors was built near the Giant's grave, about seven miles west from the base of Mt. Washington, and came into the hands of Mr. Fabyan. This was destroyed by fire about twenty years since. The Fabyan house, a large and elegant hotel, has been recently built at this place, the Giant's grave being levelled down for its reception. It was first opened to guests in 1873. The well known White Mountain house, about a mile west from this place, was built by Mr. Rosebrook, a descendant of the pioneer of that name, about thirty years since. About four miles farther west, following the Ammonoosuc river, we come to the Twin Mountain house, one of the finest and most complete of the mountain hotels. The Notch house, kept by T. J. Crawford, is no longer in existence; but its place has been more than made good by the large and well kept hotel, a quarter of a mile farther north, known as the Crawford house. At the foot of the Mt. Washington Railway is the Marshfield house, a smaller but comfortable

hotel, with accommodations for fifty guests. Upon the east side is the Glen house, at the lower end of the carriage-road. This, and the Fabyan house, are the largest hotels near Mt. Washington, either being capable of accommodating five hundred guests at one time. The Profile and Flume houses, among the Franconia Mountains, and the large and well appointed hotels of Plymouth, Littleton, Bethlehem, Lancaster, Jefferson, North Conway, and other places, too numerous for particular mention here, show the popularity of this portion of our state as a summer resort.

There are now three ways of ascending Mt. Washington from below,—two from the west and one from the east; or, a railway, a carriage-road, and a bridle-path. In 1840, the bridle-path to the summit was cut from the notch over Mts. Clinton, Pleasant, Franklin, and Monroe, to Washington, being nine miles in length. It affords a magnificent panorama of mountain scenery, passing along over the treeless, wind-swept summits of the range; but, on account of its tiresomeness, few now ascend by this route. A still longer bridle-path was soon afterwards opened by Mr. Davis over Mt. Crawford, and thence along the east side of Dry, or Mt. Washington river, but it is now wholly disused. Still later, the bridle-path first opened by Ethan Crawford from the Giant's grave to "Cold spring," or the base of Washington, was enlarged and became a carriage-road. This was in use, though kept in poor repair, till it was superseded by the "Fabyan turnpike," in 1866. It terminated about a quarter of a mile higher up the mountain than the lower depot of the railway, known as "Ammonoosuc," formerly "Marshfield."

In June, 1853, a company was chartered to build a carriage-road from the Glen to the Tip-top house, with a capital stock of fifty thousand dollars. The length of this road is a little less than eight miles. By the original design it was to be sixteen feet wide, macadamized, and to have a protection wall three feet high in dangerous places. Its average grade is twelve feet in one hundred, and the steepest is about sixteen feet in one hundred, two and a half miles from the Glen. The work of its construction was commenced in 1855, under the superintendence of C. H. V. Cavis, engineer. It was carried as far as the "ledge," or half way, in 1856, and in 1861 it was completed to the summit. There is a small house on this road half way up the mountain, at the point where the

trees terminate and the arctic zone commences. This is occupied in summer by a force of laborers, by whom the roadway is kept in a first-rate condition. But the greatest triumph of engineering skill is on the west side of the mountain, and was first projected while the carriage-road was in process of construction, but was not realized till several years later.

The first effort, in the direction of ascending Mt. Washington by steam-power, was made by Mr. Sylvester Marsh, now residing at Littleton, N. H., and the president of the Mt. Washington Railway Company. He invented the special contrivances needed to adapt motive machines to a highly inclined plane. It was found very difficult at the outset to convince mechanicians and capitalists of the feasibility of this ascending railway. Mr. Marsh commenced the work, relying chiefly upon his own private resources, and little encouragement was afforded by capitalists till an engine was actually running over a portion of the route. In 1858 the application was made to the legislature of New Hampshire to grant a charter for a steam railway from their bases to the summits of Mts. Washington and Lafayette. A model of the invention was exhibited, and it was stated that the petitioner and his friends would assume the expense of the enterprise. After considerable ridicule, this charter was charitably granted, with the usual formula of railroad laws in the state. The actual work of construction was delayed for a number of years. As a preliminary operation it was found desirable to build the new turnpike, already noticed, from the stage road to the point where the ascent by rail should commence, upon which work was begun in April, 1866. Some five miles from the starting-point this road passes through a clearing of perhaps a hundred acres, called "Twin River Farm." This spot is about five hundred feet above the White Mountain house, and is spoken of as possibly the site of the future junction of the Mt. Washington Railway with the extension of the Boston, Concord & Montreal Railroad branch from near Littleton, now nearly completed to the Fabyan house.

The Mt. Washington railroad was commenced in May, 1866. It starts from a point 2,668 feet above the level of the sea, and 3,625 below the summit. The distance traversed is two miles and thirteen sixteenths. The average grade is 1,300 feet to the mile, the maximum being 1,980 feet to the mile, or thirteen and a half inches to the yard. There are

nine curves on the line, varying from 497 to 945 feet radius. The first year the road was built a distance of about a quarter of a mile. In 1867 the track was extended to "Waumbek Junction," where it crosses Fabyan's foot-path, a distance of one mile and eight rods. Work was resumed May 7, 1868, and in eighty-four working days it had advanced more than a mile, or to the top of "Jacob's Ladder." The work was continued till cold weather set in, and the last few rods of the track was laid in July, 1869. The road was built under the superintendence of J. J. Sanborn, of Franklin, N. H., at a total cost, including depots, turn-outs, and rolling stock, of about $150,000. The indispensable peculiarity of this railway is its central cog-rail, which consists of two pieces of wrought angle iron, three inches wide and three eighths of an inch thick, placed upon their edges, parallel to each other, and connected by strong iron pins an inch and a half in diameter, and four inches apart from centre to centre. The teeth of the driving wheel of the engine play into the spaces between the bolts, and, as it revolves, the whole engine is made to move, resting upon the outer rails. These cog-rails cost about two dollars per foot, delivered at the base of the mountain. The appliances for stopping trains are of the most perfect kind. Both friction and atmospheric brakes are employed, and their complete reliability has been proved by the severest tests. The speed of descent is entirely regulated by their means without the use of steam. The engines employed have been built by Walter Aiken, of Franklin, N. H., each weighing six and a half tons, and rated at about fifty horse-power ; but on account of their gearing they are practically two hundred horse-power. When moving, the engine always takes the down-hill end of the train. While this railway was in process of construction it was visited by a Swiss engineer, who took away drawings, etc., of the machinery and track, from which a similar road has been since built upon Mt. Rhigi in Switzerland : and thus we have set an example worthy of imitation to an older country. This road has a double track, and its length and grades are about the same as upon Mt. Washington.

Casualties upon Mt. Washington.

Before the construction of these improved and even luxurious methods of ascent, several persons had lost their lives in attempting to climb this

mountain, generally in consequence of neglecting the advice of guides. The first was an English baronet, named Strickland. He went up from the notch late in October, 1851. Disregarding the advice of his guide, he pushed on to the summit, proposing to descend by Fabyan's path. He seems to have become bewildered, and, after falling down precipitous places several times, to have perished from cold and exhaustion, probably in less than twelve hours after he started.

On the 24th of September, 1855, Miss Lizzie Bourne, of Kennebunk, Me., perished within thirty rods of the summit. With an uncle and cousin she climbed the mountain on foot; but after reaching the Half-way house the clear sky disappeared; they became enveloped in a thick cloud, and strong winds met them in front. Not knowing their nearness to the summit, they were compelled to shelter themselves behind a few rough stones; and Miss Bourne was not strong enough to survive the shock. A pyramid of stones close to the railroad marks the spot.

August 7th, 1856, Benjamin Chandler, of Wilmington, Del., started from the Glen house for the summit late in the afternoon. It was rainy, windy, and very cold. He was about seventy-five years of age. He seems to have wandered from the path, but no one knows how long he survived. His remains were not found for more than a year, when they were accidentally discovered about half a mile east of the summit.

The most terrible exposure which any person has survived upon Mt. Washington was that of Dr. B. L. Ball, of Boston, late in October, 1855. This gentleman walked from the Glen house to the Half-way house, while workmen were engaged in building the carriage-road. The mountain was covered with clouds, and, after climbing some distance above the "ledge," he returned to the camp and spent the night with the laborers. The next morning the clouds seemed about breaking, and he started with the intention of reaching the summit if possible. The rain was changed to sleet and snow, and the temperature fell very much. Though very uncomfortable, Dr. Ball believed himself to be near the summit, and struggled on, understanding that he could find provisions and shelter in one of the houses there. He describes the storm as follows: "I could not have believed that the storm could be more violent than it had been. Yet here it was more furious than ever. It now had the full sweep of the mountain top, the highest point of the whole group,

of the loftiest mountain for hundreds of miles around. If ten hurricanes had been in deadly strife with each other it could have been no worse. The winds, as if locked in mortal embrace, tore along, whirling and twisting, and mingling their roaring with the flinty rattling of the snow grains in one confused din." Dr. Ball did not, however, actually reach the summit, and, after many hours spent in the endeavor, buffeting the storm, he was obliged to abandon his purpose, and set out to descend. But his footprints had been obliterated by the storm, and, losing his way, he found himself unable to judge from what direction he had come. He pursued his way downward, however, till he reached the stunted and tangled growth of spruce at the upper limit of trees. Here night came on, and, building himself a sort of shelter from the wind and snow with the aid of an umbrella, he lay down, knowing that to yield to sleep would be fatal. The night was bitterly cold, water being frozen thick at the camp below in a room adjoining one which had a fire. But even in this situation, he remarks,—"It was not without some satisfaction that I looked around me, and beheld the results of my labors. Notwithstanding the open front, a bed of snow, a frosty rock on one side, a congealed mass of snow and brush on the other, I was happy in the reflection that my lot here was infinitely better than it could have been outside. Drawing myself up into as small a compass as possible under my covering, I prepared to pass a long, *long* night,—the longest of my life." He says that he was enabled to keep awake by the multiplicity of thoughts which crowded through his mind, and by taking constrained and almost constantly varied positions. "When the first rays of light appeared in the morning, so much sooner had the night passed than I had expected, that I presumed the moon was shining. My body was stiff and rigid with cold, and pressing upon the ground with such a senseless weight, that it seemed to me I had become a part of the mountain itself." The second day the view was still obscured by clouds, and was spent by him wandering about in the snow. Unable to obtain a sight of the Glen house below, and not daring to descend into the mazes of the forests, he returned to spend a second night in the same place as before. During this night, he says, "the thought occurred, What if I am obliged to stay out a night after this, without food, drink, or sleep? After a short consideration, taking into account my present state,—that which had passed, and the

chances to come,—I concluded that, terrible as it might be, I should be able to survive it; but whether I could then walk or not, I was unable to decide." The next day was clear; but not being able to make out the Glen house, as soon as he was able to walk, which he says was after about two hours, he started out to make a circuit for its discovery, higher up the mountain. On this day he says that he no longer felt the gnawings of hunger, but was oppressed by a burning thirst. "I thought I should not wish to eat, even were food at hand. But I could not remain ignorant of the fact that I was becoming weaker. This I perceived by the effort I was obliged to make to hold my body erect, it inclining to stoop forward like a man bowed down with old age. Often I raised myself upright, but was very soon in the same bent posture." He was found in the afternoon of this the third day of his exposure, still in good spirits, after having endured for sixty hours the severe cold of the mountain, without food or sleep. The party by whom Dr. Ball was rescued, consisting of Francis Smith, J. S. Hall, and others, had been also engaged the preceding day in the search, but had given up all expectation of meeting with him alive.

On February 22, 1872, private William Stevens, of the Signal Service, U. S. A., died, after a sudden attack of paralysis. It does not appear that this malady was induced by the special perils of the service, as he had spent a winter in Alaska, and another at Fort Russell, though an unnecessary yielding to sedentary habits may induce disease in the most vigorous constitution. The body of Mr. Stevens was brought down the mountain by a party of six persons, and buried at Littleton.

During the summer of 1873, one of the section hands on the railway met with a fatal accident. He was sliding down the middle rail on a board, and collided with an engine which was coming up the mountain. His velocity of descent (a mile per minute) prevented him from stopping, and his head was split entirely open. The site of the accident was at Jacob's Ladder.

Winter Visits to the Summit.

The thrilling and melancholy recital of such events as these has not failed to invest the mountains with something of tragic interest. Their changeableness in atmosphere and temperature, the impenetrability of their fogs, and the suddenness and merciless fury of their storms, often

demand precaution and judgment in summer visits to their summits. Previous to the expedition of 1870, few had been found so hardy as to attempt the ascent in winter. In the month of November, 1855, a month after Dr. Ball's experience, another party succeeded in reaching the top in safety, and in enjoying a good view. One of the most hardy men, in the party that rescued Dr. Ball, said that with a friend he attempted to make the ascent in February; but when they arrived within a mile of the summit, they were obliged to turn back almost frozen. Before 1870, only two instances are recorded of visits to the summit during the winter months. The first was made December 7th, 1858, by Mr. Osgood, of Lancaster, who went up, accompanied by one or two friends, to serve a legal process upon property there. They found frost formed upon the windows a foot and a half in thickness. It also covered the furniture and the walls, giving them the appearance of a "snow cavern." On their return, they were overtaken by one of the frost clouds peculiar to the mountains in winter. "When first seen it was small in magnitude, but it increased in size with alarming velocity, soon spreading over the entire south. They had just entered the woods at the base of the ledge, when it came upon them. So icy and penetrating was its breath, that to have encountered its blinding, freezing power on the unprotected height, would have been to have perished with it as a pall to cover them. The party reached the Glen in safety, and were heartily welcomed by their friends, who, well knowing the danger attending this never before accomplished feat, awaited them with much anxiety."

The other ascent was made by a party of three,—J. H. Spalding, F. White, and C. C. Brooks, all from Lancaster,—on February 11, 1862. A stereograph, obtained at this visit, exhibited the interior of the Summit house, with snow-drifts which had been sifted in through cracks in the building. This party remained on the top two days and nights, experiencing a driving snow-storm of thirty-six hours' duration, and were repaid by "one of the most magnificent sunrise scenes that imagination can picture." The most extreme cold during their stay was five degrees below zero. One of the objects of this visit was evidently to obtain some acquaintance with the storms of the mountain. Their account concludes: "We were remarkably well satisfied with the weather, and were very lucky about climbing over the ice-clad rocks. Should others attempt to

go up among the clouds, for their own sake they should go prepared for the worst. An iron-pointed staff, with an axe, and plenty of food and clothing, are indispensable."

In the winter of 1870–71, the possibility of climbing the mountain in the winter was thoroughly established. Thirty-eight persons went up and down,—some of them several times,—the total number of ascents being seventy. A register of the trips was given in the report for 1870. The expedition was undertaken in opposition to the judgment, experience, and advice of those most familiar with the mountain.

Mrs. O. E. Freeman, of Lancaster, made the ascent of Mt. Washington, Tuesday, January 24, 1874, on foot. She is a daughter of "Old Ethan Crawford," of White Mountain fame, and is doubtless the first woman who ever attempted to accomplish his feat in winter. She was accompanied by her sister Mrs. Durgin, her brother William H. Crawford, and nephew Ethan Crawford, Jr. They did not anticipate going to the top at the starting, but thought they would walk up a short distance to see the railroad, etc. They finally concluded to go to the top if possible, and made the distance in three hours, walking upon the railroad sleepers most of the way,—which required not a little self-possession and endurance, as they are in many places ten and fifteen feet above the rocks below, and covered with ice and snow, so that a single misstep might prove fatal to one walking upon them. Having been born under the very shadows of these grand old hills, these ladies have become inured to cold, frost, and snow, and enjoy rather than shrink from a little exposure. Mrs. Freeman describes the trip as "glorious fun," and expresses the hope that all her lady friends may have the pleasure of making it in winter.

Establishment of an Observatory.

The increasing interest during the past few years in the subject of meteorology, the remarkable character of the phenomena which would be observed during a winter residence on any of these mountain summits, and, within the last few years, the obvious bearing which these must have upon the great problem of meteorology, the prediction of the weather, together with the expensive outfit which it was seen must be necessary to render such an enterprise possible, seem to have given rise to many stories of large rewards which had been offered to any one who should accomplish this object. As long ago as 1858 a report was current, among guides and others, that the Smithsonian Institution had offered a thousand dollars to any one who would spend a winter on the highest summit, for

the purpose of taking meteorological observations. Others said that a firm in Boston had offered five thousand dollars for the same object, with the avowed purpose of publishing the journal of the observers' experience, expecting to be reimbursed for the large expenditure by the sale of the books. In the efforts during the fall of 1870 to raise funds for the meteorological expedition then undertaken, every such report was carefully scrutinized, but none could be traced to any reliable source. Even to the present time, people at the mountains still insist that somebody had offered a very large sum for the purpose accomplished by the Mt. Washington expedition.

Perhaps the first attempt to establish a scientific observatory upon the summit of Mt. Washington was made in 1853, by D. O. Macomber, president of the Mt. Washington Road Company. I have seen no one who recalls the extent of the effort made at this time, but can reproduce a circular setting forth the importance of the enterprise, and a petition to congress for assistance.

"United States Observatory on Mt. Washington.

"The arguments in favor of establishing a permanent building on the top of Mt. Washington, for scientific purposes, are numerous and weighty. Among them are,—

"1. Mt. Washington is the highest accessible point of land in the United States, east of the Rocky Mountains, being 6,285 feet above the level of the sea, according to actual measurements made by William A. Goodwin, Esq., civil engineer, in 1852, who was employed for that purpose by the Atlantic & St. Lawrence Railroad Company.

"2. The construction of a Macadamized carriage-road, chartered by the state of New Hampshire, in July, 1853, and which will be completed in 1854, will render the ascent of the mountain easy for such portions of the year as it is desirable to continue scientific observations.

"3. A line of telegraph is to be constructed to the summit of Mt. Washington, connecting with the line now in operation from Portland to Montreal, and which line connects at Portland with lines to Boston, New York, Washington, Cincinnati, &c., &c.

"4. A large hotel is to be erected on the top of the mountain by the Mt. Washington Road Company, which hotel, together with the necessary out-buildings, will occupy *all* the available space on the summit which is suitable for such purposes, and which is already laid out and commenced, and will be completed during the year 1854. The company who erected the first building of any kind on the summit, form a portion of the present incorporation, and merge all their interests in the new building.

"5. It has been satisfactorily ascertained that no private individuals have any title to the surface of the summit of Mt. Washington, but the same is held by the state of New Hampshire, from whom and by the legislature of which the charter of the Mt. Washington Road Company was granted.

"6. When the building, with an observatory attached, shall be completed, and furnished with the necessary instruments, scientific observations may be kept up throughout the entire year, giving, over the telegraph wires to Washington, New York, Cincinnati, &c., three times each day (viz., sunrise, meridian, and sunset), the record of the thermometer, barometer, and wind, and also the duration and power of storms.

"7. Mt. Washington has been for years past, and will be for years to come, the culminating point of many of the most important and interesting observations connected with the coast surveys under charge of Prof. Bache, and which are now becoming of so much acknowledged practical utility to the great commercial interests of the United States, and of the world.

"8. It is evident that if an observatory, for the use of the government and the benefit of the public, is ever to be erected on the summit of Mt. Washington, it should be built in connection with the house now about to be commenced, and both constructed in the most durable and permanent manner, not only to resist the force of the elements, but also for the safety and comfort of those whom it may be necessary to station there during the winter season for scientific observations, and who will be wholly inaccessible to those below for at least five consecutive months.

"9. The proposition to the United States government will embrace all the advantages of furnishing an excellent road for its use, and keeping the same in repair, erecting a tower for scientific observations, with movable dome, and with a centre isolated pillar on which to place instruments, with sufficient rooms for observations, and also for the use of any scientific corps it may be necessary to place there, with appurtenances for heating the same during the winter months. These rooms, together with the observatory, to be entirely under the control of the government, and, if desirable, built under the inspection of scientific gentlemen to be named by the president."

"*To the Honorable Senate and House of Representatives of the United States in Congress assembled:*

"The president and directors of the Mt. Washington Road Company propose to the United States government to build, for the use of the government and for scientific purposes, an observatory on the top of Mt. Washington, in the state of New Hampshire, in the manner following, to wit:

"1. The observatory to be 25 feet square, with walls 4 feet in thickness, and to be not less than 40 feet high above the top of Mt. Washington.

"2. The rooms inside to be 17 feet square, or of an octagon form, and a stone pillar to be erected in the centre from the foundation to the top, entirely disconnected with

the walls, with stone beams projecting from it in the several stories, for the reception of transit instrument, transit clock, artificial horizon, &c., &c.

"3. The walls of the observatory to be built of stone, in the most substantial and durable manner, with a traversing dome, fitted according to the most approved scientific buildings of this character.

"4. The observatory to be erected as a tower to, and in connection with, a large substantial stone building, 110 feet long by 50 deep, with an ell 90 by 40. The whole to be three stories high, with flat roof, and calculated to accommodate one hundred and fifty visitors during the summer months.

"5. The Mt. Washington Road Company, under their charter of incorporation, a copy of which is herewith submitted, will build a substantial carriage-road from the base to the top of Mt. Washington, with a grade not exceeding one foot in eight, and eight miles long, to be completed before July, 1855.

"6. The company will place this road at the service of the U. S. government, and will transport all instruments, furniture, and persons belonging to or connected with the government observatory, over the same, free of charges of any kind, at all times when the said road shall not be rendered impassable by the elements.

"7. The Mt. Washington Road Company will erect, or cause to be erected, a substantial line of telegraph wires from the top of Mt. Washington, to connect with the line already in operation along the line of the Atlantic & St. Lawrence Railroad, which is distant only eight miles from the base of the mountain, and which telegraph line connects at Portland, Me., with the lines extending to New York, Philadelphia, Boston, Washington, Cincinnati, and other portions of the United States.

"8. To facilitate the continuation of scientific observations during the entire year on the top of Mt. Washington, the Mt. Washington Road Company will place at the disposal of the U. S. government such portion of the building as shall be necessary for the accommodation of those who may be in the employment of the government, or of any scientific society approved of by government, without charge, and will transport at their own cost over their road, all fuel, provisions, &c., for the support and convenience of such persons.

"9. To enable the Mt. Washington Road Company to build this national observatory in the manner stated above, and in accordance with plans of the same herewith submitted, and for the furnishing a carriage-road, telegraph communication, and all the facilities above stated for the use of the United States government and the cause of science throughout the world, they ask, in consideration, an appropriation of $50,000, to be expended under a joint commission of two persons, the one to be named by the government, and the other to be the president of the Mt. Washington Road Company.

"D. O. MACOMBER, *President Mt. Washington Road Company.*

"December 1st, 1853."

In 1859, Jonathan Marshall, a recent graduate of Dartmouth college, conceived the idea of spending a winter upon the summit of Mt. Wash-

ington for meteorological purposes. He received encouragement from Prof. Joseph Henry, of the Smithsonian Institution, and was allowed to occupy one of the houses. An unexpected snow storm delayed some of his preparations, and meanwhile other considerations prevented him from carrying out the enterprise.

The history of the successful establishment of the observatory, in connection with the geological survey, will presently be given in full.

Fig. 10.—SUMMIT OF MT. WASHINGTON FROM THE NORTH.

Depot and Summit House in 1870.

Signal Service Occupation. Mt. Washington has been occupied as one of the stations of the signal service since its abandonment by the geological survey, in May, 1871. Sergeant T. Smith was relieved by Sergeant M. L. Hearne, in June, 1871. Sergeant Hearne was assisted by private William Stevens, till his death, Feb. 22, 1872,—his place being taken by Robert J. Bell. They arranged a box like a chimney, extending above the ridge-pole, so that they could climb up and expose the anemometer without going out of doors themselves. The head is protruded a single instant, in order to place the instrument properly; and the sensation experienced, when the wind is blowing at the rate of ninety miles to the

hour, is said "to be the same as if a bucket of water were thrown suddenly into the face, and immediately frozen thereon."

November 14, 15, and 16, 1871, are reported by Sergeant Hearne as very "stirring times," his instrument recording the most rapid movements of air ever described. At 9 A. M., Nov. 14, the wind blew at the rate of 40 miles to the hour. At 4 P. M., it reached 60; at midnight, 78, and still increasing, with snow and sleet,—the barometer sinking four tenths of an inch during the night. At 6 A. M., the 15th, the wind tore off five or six planks from a corner of the building. At 7, the rate of velocity was 102; at 9, 120; at 3 P. M., 136 miles. The building cracked, shook, and groaned to its very foundation. At 4 P. M., it blew at a steady rate of 140 miles, and three more planks gave way. At 5 P. M., two trials gave 150 and 151 miles per hour. This was the culmination of the storm, and the wind gradually died away during the 16th inst. Meteorology does not yet furnish the record of a more fearful storm than this experienced by civilized beings.

Sergeant A. R. Hornett succeeded Hearne, and has already spent two winters on the summit, assisted by Sergeant Wm. Line, Fred. DeRoshers, and others. The party now consists of three persons. In 1873, a building was erected for the occupation of the government party. It is situated a few rods south of the hotel, in a very exposed situation. It is thirty-six feet long, and twenty-four wide, containing an office, dining-, store-, and two bedrooms, besides an attic. It is built of wood, and is situated so that the grandest views can be seen without leaving a comfortably warmed apartment.

THE OCCUPATION OF MOOSILAUKE—WINTER OF 1869–70.

With the commencement of work on the geological survey of the state in 1869, this subject of an elevated winter observatory was early discussed, Mr. Huntington being prepared to occupy the position of observer. But it was found that the lessee of the houses on the summit of Mt. Washington was unwilling that they should be occupied for this purpose during the winter. While this unexpected refusal deferred the occupation of Mt. Washington, it led to a successful attempt in a different direction. Had the observatory been established in 1869, it might have been a failure, from the want of an experience of the peculiarities

of mountain atmospheric phenomena. The defeat of our plans coming to the knowledge of Mr. William Little, of Manchester, the owner of the house on the top of Moosilauke, he generously offered its free use for the occupation of Mr. Huntington's party that winter. The proposal being made to Mr. Huntington, he adopted it without hesitation, although, in consequence of bad chirography, "Moosilauke" was mistaken for "Monadnock." Moosilauke, situated in Benton, is some twelve or fifteen miles distant from the Franconia range, and in a fully exposed position, being nearly five thousand feet high, and within the Arctic zone of climate.

It was late autumn before any preparations were made. Wood and provisions had to be hauled up a mountain bridle-path more than a mile; and it was necessary to fit up a comfortable room. On the 23d of November, an ascent, to make these preparations, was attempted. The day was unfavorable; and, upon reaching the bald portion of the mountain, nearly a mile from the house on the summit, the party were met by such a furious storm of wind and driving snow that they were obliged to retreat. The following day, however, the attempt was successful; and three days were spent in arranging for winter quarters. On the last day of December, Mr. Huntington finally ascended the mountain, to remain for two months, accompanied by Mr. A. F. Clough, photographer, of Warren, whose enthusiasm, backed by resolution and great powers of physical endurance, proved of the greatest value, both in this and the Mt. Washington expedition. The limited supply of provisions which had been taken up necessitated a short stay; and the descent from the mountain was made on the last day of February. It may be proper to add that the whole expense of this expedition was borne by those who participated in it, chiefly by Mr. Huntington.

By the two months spent on this summit, the possibility of living on a mountain top during the winter was fully demonstrated. The observations made were published in the newspapers; and the public were, to some extent, prepared for the expedition of the ensuing winter, for which ways and means began to be early devised.

The following extract will be read with the greater interest, since the author—though the strongest, on both mountains—has been the first to yield to the attacks of disease. He died of gangrene on the lungs, in 1872.

Extracts from the Diary of A. F. Clough, kept upon the Summit of Moosilauke in 1870.

January 27. Mounted my snow-shoes, took an axe and an old iron tea-kettle, and started for Jobildunk ravine. Splendid view there,—ice columns a hundred feet high. What a time I had getting down to the foot! First, I sent the axe down on a voyage of discovery, and to bush out a path. How it leaped and slid and plunged, as it went down to the woods a thousand feet below! Next went the snow-shoes; but the kettle would be smashed, and I kept it along with me. Then I slid a little way; clinging by the bushes and holding to a birch, got down a perpendicular descent some ten feet. From this I could not get back at all, or down, except by jumping. Then I sent the tea-kettle ahead. It went leaping and whirling twenty feet at a bound, smashed in pieces, and was lost in the firs. I never saw it again. I looked over the precipice. There was a shelf of the rock twenty feet below, and a snow-bank on it. It was the only way. I jumped, and settled to my knees in it. The rest of the way was easier; and, sliding and jumping, I was at the foot in almost no time. It was a wild, grand scene, ice precipices rising one above the other a thousand feet, till the tops are lost in the clouds. Spotted my views; and was two hours climbing home through the woods. The ravine is one of the wildest places in New Hampshire, especially in winter. The Asquamchumauke comes down through it.

February 18. Storms. Well, I like a storm; it arouses peculiar feelings, excitement, when it goes in strong, and it does that to-day, sure. One incessant roar all day, driving sleet and rain. The house shakes and trembles, though one side is buried in a snow-drift to the top of the roof, nearly, with five inches of snow and ice on the roof and walls.

10 A. M. Went out with the anemometer. We had a barrel set for the purpose; but the snow and ice had filled it up, so I held the machine for ten minutes. Sat down, back to the wind, astride of the barrel. It was no boy's play. Machine won't weigh five pounds, but it tired me terribly. The wind would ease a trifle, then come with a rush and a roar louder than thunder, that made me cling, legs and arms, to the barrel. The roar was deafening;—I could not hear. Huntington gave signal with his hand, and I made for the house; was thrown flat down by the wind, then crept in. How queer I felt. I reeled and staggered like a drunken man. My head was giddy, my eyes on fire, a thrill like electricity shot through my whole body, making me wild and reckless. How it would have operated had I stopped longer, I cannot say. I should be careless of my life to try it again. The wind is blowing a hundred miles an hour; the sleet cuts like a knife; and my skin smarts wherever it was struck.

Blows like great guns this afternoon. Rain comes down a perfect shower; runs in streams about our window. We have got pails, buckets, kettles, &c., to catch it, and keep from being drowned out. This is worse than the storm of January 2; but we are better prepared to meet it.

8 P. M. No abatement in the storm yet. Blow, blow! I like it; it is like a roar of thunder all the time.

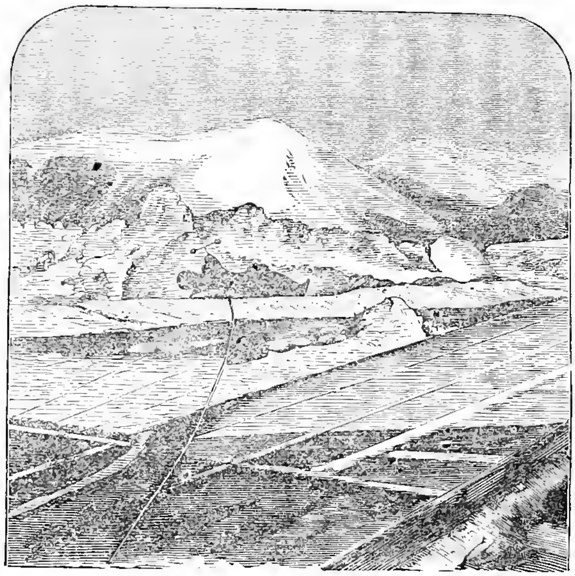


FIG. 11.—MEASURING THE WIND.

Velocity 88 miles per hour.

10:30 P. M. Still continues. Wind howls now like ten thousand fiends let loose from the infernal regions.

February 19. Well, the storm has spent its fury at last. The wild, deafening roar has died away, but occasional gusts sweep along, sighing with a low moan, the last dying throes of the wild, terrifying hurricane. It began to abate last midnight. Would like to have the clouds lift a few minutes, to see how it served people down on earth. Huntington has gone down, and when he comes back he will report.

It takes a blow from the south-east to get up a storm and to keep it going. It also takes a blow from the north-west, up in this altitude, a mile above the ocean, to clear it off. It is cold to-day.

This afternoon we got frost clouds,—"clouds made up of minute particles of ice, said to bring death to any one caught in them." That story is a myth. [See page 86.] We found them as harmless as a summer vapor.

February 20. Thermometer 14° below; clear and pleasant. *Looked away to the south-east, and saw the ocean.* Walked down to the ravine; got a fall, and slid down a hundred feet; brought up in a snow-bank; was frightened, but not hurt a bit. Hackmatacks are buried in snow. Wind has changed to south-east again; another storm is on the stocks.

2. P. M. It is blowing again,—it roars again,—it howls again. I thought the wind

had blown as hard as it could, but it is now worse than ever before. I shall not wet myself to the skin again to hold up that anemometer. I know it blows at the rate of more than a hundred miles an hour. How it roars! But "roar" does n't express the noise; bellow is too tame by half. In a thunder-storm the lightning flashes, blinding the sight; then comes a sharp report, which immediately gives way to deep, reverberatory rumbling that shakes and makes everything vibrate with its power, then rolls away and is lost. Now just imagine, if you can, a continual roll of the first reverberations, after the sharp report is over, and you will have some faint idea of what we have this day,—a continual thunder, making everything shake for hours together. Have storms like this swept over these mountains for thousands, perhaps millions, of years? or, is this a special storm for the benefit of us two poor mortals who have invaded this bleak and lofty region? Can't tell.

February 21. Snows; and there is a drift fifteen feet high on the south side of our house. Had to shovel out our window to let in daylight.

1 P. M. I am writing by lamplight;—the house is completely snowed up.

February 22. Thermometer 17° below. House still snowed up;—time drags.

THE MT. WASHINGTON EXPEDITION—WINTER OF 1870–71.

This expedition, like that upon Moosilauke, was undertaken for the purpose of contributing something to the solution of the great question whether science can forecast the weather for hours and days beforehand. It was deemed especially important to investigate the meteorology of Mt. Washington,—the highest point of land in the eastern United States,—as, from its exposed position, it might be expected to give the first indications of approaching storms. The observations upon Moosilauke had afforded valuable experience for this more extended expedition, and had already given some indication of the phenomena peculiar to the higher New England summits in winter. As nothing of this kind was contemplated in the original act establishing the geological survey of the state, it was not possible, nor desired, to use any of the funds appropriated to geological exploration for meteorological purposes. With the approval of the state authorities, the geological survey adopted the expedition as a part of its work, and obtained the requisite funds entirely by subscription. The total amount expended, including the value of materials and other substantial aid furnished, reached as high as $3,500.

In the preparations for this expedition a house was, of course, the first essential. Application was again made for the Tip-top house: this was met by a courteous but firm refusal. At one time the question of build-

ing a small house was discussed. From his elevated observatory on Moosilauke, Mr. Huntington, by letter of February 18th, 1870, had proposed that negotiations be commenced with the Mt. Washington Railway Company for the use of the engine-house or depot they were intending to build on the summit. After the adverse decision in regard to the Tip-top house, a letter was addressed to Mr. Sylvester Marsh, the president of this company, inquiring whether their building might not be used in the winter by the meteorological party. In reply, it was stated that the completion of the house before winter was uncertain; but a desire was expressed that the project might be successful. Interviews were had with Mr. Marsh, and he spoke even more favorably than had been expected from his letter; but he added, that he had not the authority to speak for the company. Having no reason to suppose the directors would not favor us, late in July the state geologist issued a circular, stating the importance of establishing a meteorological observatory upon Mt. Washington in the winter, and asked the friends of science to contribute the sum of two thousand dollars to maintain the expedition, and furnish the means of telegraphic communication between the observers and the public. It was stated that with this sum the expedition could be made successful, and the public would receive daily reports describing the character of the arctic phenomena peculiar to the summit, thus giving abundant opportunity for comparison with any observatory in the country. This circular was sent to friends, and small sums were received, but not to any promising extent. It was also posted at the principal hotels among the mountains, in full view of the guests, but failed to excite any special interest. The remainder of the summer was so occupied with necessary geological field-work as to leave no time to beg for money.

By the first of September not a hundred dollars had been promised. The next effort was in the direction of the press. A prominent journal in New York was willing to give five hundred dollars for daily telegrams and occasional letters sent to them exclusively during the winter. Although a telegraph line, capable of use in the winter months, was beyond the expected means, faith in ultimate success was strengthened by this proposal. About this time attention was called to the recent establishment of the "Bureau of Telegrams and Reports for the Benefit of Commerce," in connection with the War department at Washington.

Application was made to Gen. A. J. Myer, the chief signal officer, for funds to aid in carrying out this enterprise, allowing the weather office to share its benefits. The answer, dated September 14th, stated that the chief signal officer could "hardly appropriate money for the object named; but it may be in the power of this office, with the approval of the secretary of war, to detail an observer for the position you propose to occupy." In further correspondence, he stated his willingness to provide an insulated telegraph wire, to extend from the summit of Mt. Washington to the railroad station at its base; adding, however, that he could not sanction any special arrangement to furnish any one paper exclusively with the weather reports. He proposed himself to furnish weather reports from all the stations throughout the country to the principal newspapers, as well as to the chambers of commerce. He also offered to provide the meteorological instruments required for the station. Thus the means were provided for sending daily telegrams, but it necessitated a change from the proposal to send the weather reports exclusively to the *New York Tribune*, and left the enterprise as poor as ever.

In a letter of October 7th, the chief signal officer announced that he had sent to the state geologist three miles of insulated Kerite telegraph wire, two telegraph instruments, two sections, and four conductors, to the value of $1,032; and that an instructed observer would probably be detailed to join the expedition. These telegraph supplies were duly received, and immediately transported to the mountain.

From another quarter, however, there came the required pecuniary assistance. In the month of July, the state geologist learned that Mr. S. A. Nelson, of Georgetown, Mass., was very much interested in the meteorology of Mt. Washington, and would like to join the expedition. He soon after received a letter from Mr. Nelson, presenting this request, and asking also for further information. His tone of writing evinced a rare enthusiasm for the undertaking, and from further correspondence it appeared that he was ready to devote himself to raising funds for the expedition, in case he could be one of the party. A formal invitation was soon extended to Mr. Nelson, which he accepted, and immediately set himself to the task of soliciting subscriptions in eastern Massachusetts, pledging himself to procure at least $500. His promise was more than realized, for his efforts brought in more than $800. His labors com-

menced early in September, and he did not go upon the mountain till late in December, remaining behind after the occupation of the summit to complete what he conceived to be his part of the work below.

It became evident that the public were slowly gaining confidence in the success of our enterprise, and therefore we began to purchase our supplies. Mr. Huntington made out the list, that the needed articles might be at the lower mountain depot early in October, understanding that the trains could not transport freight for the expedition before that time. On the 19th of September, however, information accidentally came to the state geologist, at Bethlehem, that the mountain trains would stop running on the following day, as the track was to be taken up immediately for repairs; and that no orders had been given by the officers of the company to afford the expedition any facilities, either of transportation or the use of the summit depot. To add to these difficulties, the supplies had not all been purchased. It was uncertain whether sufficient funds could be obtained; and no arrangement had then been made for the use of a telegraph cable. Under these unpromising circumstances, the party at Bethlehem, with the exception of the state geologist, came unanimously to the conclusion that the difficulties in the way were insurmountable, and that the expedition must be abandoned for the next winter. But he said that the supplies should all go up the mountain, even if he turned teamster himself, and, with a single horse, transported them up the carriage-road,—Mr. Huntington having expressed a willingness to remain upon the summit all winter, even without telegraphic communication with the world below. The next day, therefore, one of the party went to the railroad station to say that orders were coming from head-quarters to grant the needed facilities, as they must have been delayed by some misunderstanding. Another went to Littleton to borrow a few tons of coal, that the most essential article to comfort might be sure to reach the railroad in season for transportation to the summit. Prof. Hitchcock, at the same time, went to Boston, and obtained from the officers of the company the necessary permission to use their summit depot during the winter, and immediately transmitted it to the employés. The railway company generously gave the use of the depot, and transported the supplies over their line to the summit without charge, regretting that they could not have known earlier of our purpose, so that the house might

have been completed. The necessary supplies were immediately purchased, and transported without charge from Boston to the Wing road, by the B. L. & N., Concord, and B. C. & M. railroads. After all our efforts, however, the telegraphic apparatus sent from Washington, and some other necessary articles, arrived too late for the last train; and these were taken around the mountain,—partly by Prof. Hitchcock and partly by Mr. Huntington,—and thence to the summit, on the carriage-road. The distance traversed was nearly eighty miles, over a very muddy and hilly route—a tedious journey, whose difficulties can never be appreciated by the public. Several days were spent upon the summit in preparing the building for occupation,—partitioning off a room, laying double floors, setting up the stoves, etc. Mr. Huntington remained upon the mountain till the rooms were completed for occupation, the Kerite wire laid, and

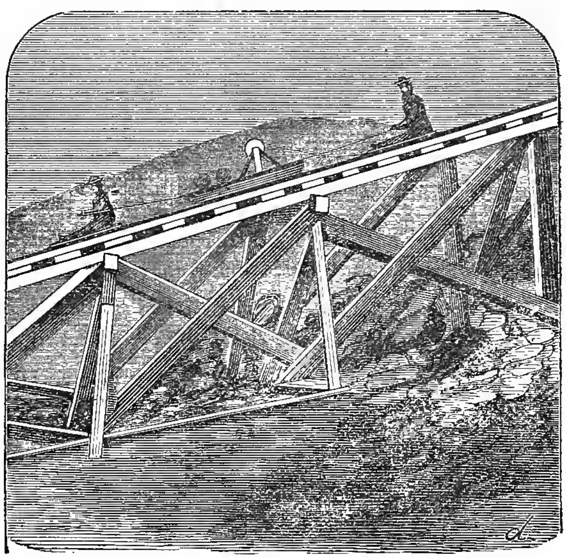


Fig. 12.—LAYING THE CABLE ON JACOB'S LADDER.

everything in readiness for the incoming of the party. He came down October 22.

A new circular, adapted to the changed circumstances, was now prepared and widely distributed. In this it was briefly stated that the arrangements for the occupation of the mountain had been completed; the observers, photographers, and telegrapher, selected; the needful

supplies purchased and transported to the summit; a Kerite telegraph wire had been laid over that portion of the route where a common wire could not withstand the wintry blasts and accumulations of ice; that the building had been secured and comfortably furnished; and, furthermore, that the party intended to establish themselves in their snug eyrie about the 12th of November. Reference was made to the approval of the expedition by the War department, and to a special letter of recommendation signed by Professors B. Pierce, Joseph Winlock, Joseph Lovering, Asa Gray, Alpheus Hyatt, President Runkle, N. B. Shurtleff, and William Claflin. It was thought that commerce would be greatly benefited by the daily reports. As the farmer studies the cloud-caps upon mountains to forecast the weather, so telegraphic reports of the condition of the atmosphere upon the highest summit in eastern America would enable ship-owners to judge of the approach of storms, and escape risk of loss to their vessels by keeping them in a harbor until the danger was past; so, too, with fair weather reported from the mountain, vessels could get a day's start of any bad spell of weather, and thus escape great peril. It was announced that the preparations for the expedition had been made with the expectation that friends would contribute funds sufficient to meet the expenses. Should the public fail to appreciate the enterprise, the burden would fall upon the state geologist, who had already paid out $700 more than the amount of the subscriptions. This appeal proved to be efficacious, as, in consequence of this and other applications, enough funds were at length secured to meet all the expenses of the expedition.

On the 3d of October, a letter was received from Mr. H. A. Kimball, photographer, of Concord, N. H., asking to be permitted to join the party and take views. According to the original plan, the artist of the expedition was Mr. A. F. Clough, who had been associated with Mr. Huntington in the occupation of Moosilauke; hence this application was referred to him, with the result that the two gentlemen concluded to combine their efforts, and go upon the mountain in company. Mr. Kimball aided, also, in the work of raising funds, adding more than a hundred dollars to the list. Both the photographers made personal pecuniary sacrifices to render their branch of the expedition successful; and their published stereographs have proved a valuable addition to its records.

On the third of November, the chief signal officer informed Prof.

Hitchcock that he would send an instructed operator and observer, with a complete set of meteorological instruments, to Mt. Washington, and requested that one weather report might be forwarded to him daily by telegraph. This report would be bulletined along with those from other stations, and a copy of it furnished to the principal daily journals in the country. After some delay, Sergeant Theodore Smith, U. S. A., started from Washington, and reached the mountain early in December.

The complete organization of the expedition was as follows:

C. H. Hitchcock, state geologist, with office in Hanover connected by telegraph with the summit of Mt. Washington.

J. H. Huntington, assistant state geologist, in charge of the observatory upon the mountain.

S. A. Nelson, observer.

A. F. Clough and H. A. Kimball, photographers.

Theodore Smith, observer and telegrapher for the signal service.

The mountain was occupied for scientific observation during a period of six months, from Nov. 12, 1870, to May 12, 1871. From that time to the present, the observations have been continued by the United States signal service, this being adopted as one of their regular stations.

Narrative of the Expedition.

The meteorological records of the expedition have been made the subject of a separate portion of this work. It has been thought, also, that, in addition to these, some account of the doings and experiences of the party while on the summit would be sought for in these pages. Extracts from the journal of the expedition, kept by Mr. Huntington, from Nov. 12 to Dec. 20, and subsequently by Mr. Nelson, together with its history from the beginning, and a statement of its results, were in due time arranged and published.* All who were connected with the expedition contributed to this work, which was "addressed, as their official report, to those friends who furnished the means of establishing this Arctic observatory." Portions have been selected from this work for presentation here, so far as to show some of the most noteworthy experiences of a life in winter upon Mt. Washington.

* Mt. Washington in Winter. Boston: Chick & Andrews, 1871.

Mr. L. L. Holden, correspondent of the *Boston Journal*, visited the mountain February 8, and again April 29. He describes the quarters occupied by the party as follows:

The depot was built last summer, and occupies a site of the same elevation as the Tip-top and Summit houses, north-easterly of those structures, upon the verge of the little plateau forming the summit of the mountain. The building, unlike the two diminutive public houses, whose sides are of stone, is constructed wholly of wood. It is sixty feet long by twenty-two feet wide, and stands nearly north and south. It has eleven feet posts, and the elevation of the ridge-pole is twenty-five feet, the roof being of the same form as the roofs of ordinary buildings. The apartment inhabited by the party is situated in the south-east corner of this edifice. It is a room about twenty feet

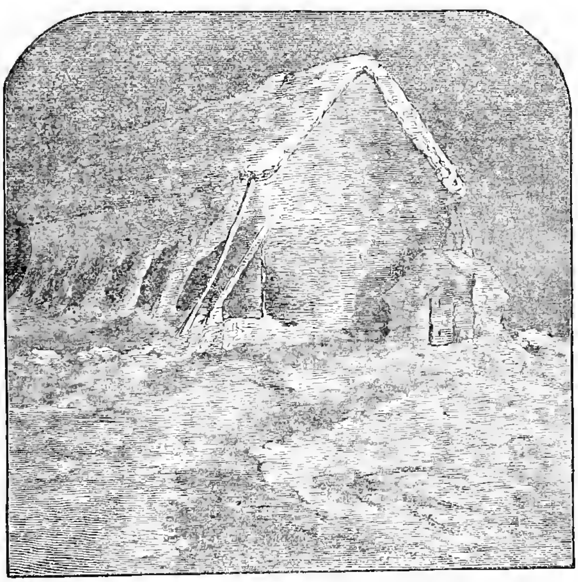


Fig. 13.—THE HOME OF THE EXPEDITION.

long, eleven feet wide, and eight feet high. The larger portion of the depot forms a sort of vestibule to this room, and is wholly enclosed, except at the easterly end of the northern face, where the outer door is situated. The little room was formed in the following manner: 1, there was the thick plank floor of the depot itself, which constituted a good foundation to build upon; 2, a course of sheathing paper was laid over the original floor; 3, an additional floor of close-fitting boards was then laid down; 4, two thicknesses of sheathing paper were placed on the top of the second floor; 5, a layer of carpet lining was added; and 6, a thick woollen carpet was made the uppermost layer of all. The inside of the outer walls was covered first with tarred paper,

then with boards; a layer of sheathing paper was added, and wall paper spread upon this. The ceiling is formed of two thicknesses of boards with sheathing paper between, and the inner walls consist of single thicknesses of boards, sheathing paper, and wall paper. There are two double windows, or rather half-windows, on the westerly side of the room, and these are protected by strips of board without. The door of the room is of ordinary size, but the outer door is nothing but a little opening two feet square, some two feet from the floor.

We have thus far described none of the precautions taken to prevent the building from being torn to pieces by the terrible winter tempests, or from being blown away altogether. The frame-work is of the strongest possible kind, and is fitted together in the best manner. The sills extend beyond the walls eight or ten feet, and every means are taken to fasten the structure down to its rocky base. Within, bolts, iron rods, and wooden braces add strength to the walls, and three strong iron chains, securely fastened to the rocks, pass over the roof. Notwithstanding all these provisions, the building rocks and bends before a furious wind-storm in a manner well calculated to create consternation and dismay. An ordinary house would stand no longer before such terrific blasts than would a house of cards before an ordinary wind. The great gale in December awakened the fears of the party for the safety of the depot, but, as the structure stood that frightful assault, it was thought no further danger on that score need be apprehended. It was nevertheless thought best to strengthen the walls with additional braces and supports.

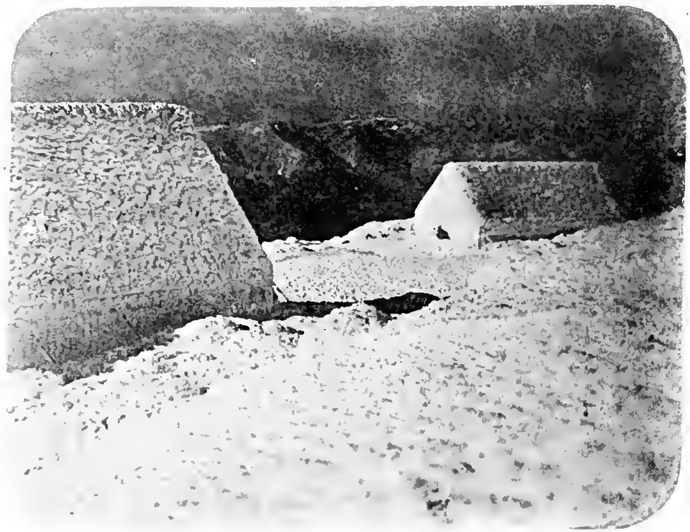
The work of the expedition was begun by Mr. Huntington, who ascended November 12, and was for nearly three weeks alone upon the mountain. We copy from his journal:

November 12. Started from Marshfield at 7 A. M.; arrived at the summit of Mt. Washington at 9:30. It rained until I got within three fourths of a mile of the summit; then there was a frozen mist. The snow was six inches deep at Ammonoosuc; at Waumbek Junction, a foot. At the second tank the snow was drifted; none on the ties above. On the summit it was drifted so that neither at the Summit nor the Tip-top house could the doors be seen; there was very little about the depot. I am here alone, but should have come if I had known that I had to stay alone all winter.

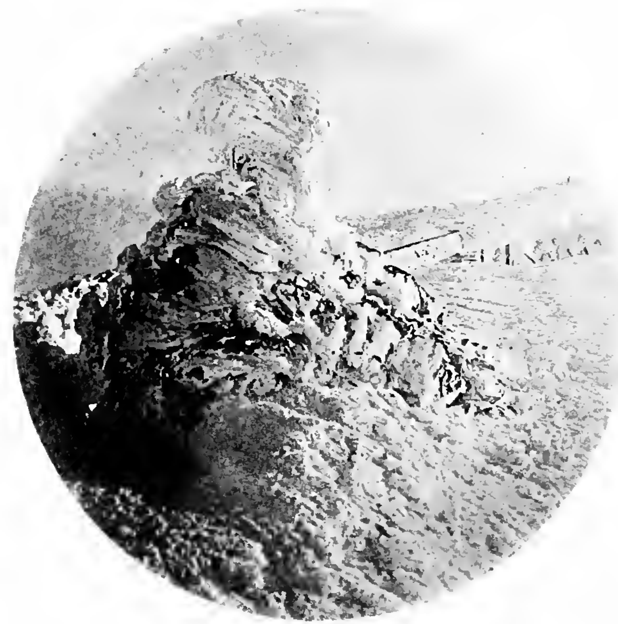
November 15. Have been above the clouds all day long. Some of the time not a single mountain top could be seen. Occasionally Mts. Adams and Jefferson would appear, but most of the day in every direction was this illimitable sea of clouds.

November 24. The barometer lower this morning than it has been before. Wind blowing fiercely from the north-west, not steadily, but in gusts. The house creaks in every joint. It is something fearful to sit here alone and hear the wind howl, while showers of ice are blown against the side of the building and along the roof.

November 30. Clear until 2 P. M., when light clouds began to pass over the moun-



The Carter Range.



Bourne Monument.

tain, but became dense toward night. Was surprised by the arrival of Clough, Kimball, Cheney, and Bracy. I am not likely to be alone again this winter.

December 4. Sergeant Smith arrived to-day.

December 12. Clough and Smith went down to the base of the mountain, and as they returned found that the wire would work to the second tank, but could get no current on the summit.

December 13. The telegraph worked to-day for the first time. Now we are in the world again.

The ascent of the photographers, Messrs. Clough and Kimball, accompanied by two friends,—Charles B. Cheney, of Orford, and C. F. Bracy, of Warren,—upon Nov. 30, was accomplished under circumstances of great difficulty. The party had been delayed in reaching Ammonoosuc by being unexpectedly obliged to chop a passage-way through trees which the wind had thrown across their road; and it was past the middle of the afternoon before they could start on the ascent. But, as the weather appeared propitious, they decided to advance, having been already delayed several days beyond their original plans. The following description of their experience was prepared by Mr. Kimball, whose strength proved unequal to the severe task when suddenly overtaken by one of the fierce mountain storms.

The end of the first mile, carrying us up to within one half mile of the limit of wood-growth, found us in tolerable condition, when a halt, for breath and observation, discovered to us an approaching storm lying on the Green Mountains of Vermont. It would undoubtedly strike us, but we still hoped that we might press on and reach the summit first. The thought of being overtaken by a furious storm, on the wintry, shelterless cliffs of Mt. Washington, with the night about to enshroud us, was fearfully impressive, and prompted us to our best endeavors. With all the effort we could well muster, we had only advanced a half mile more, carrying us fairly above the wooded region to the foot of "Jacob's Ladder," when the storm struck us. There were suddenly wrapped around us dense clouds of frozen vapor, driven so furiously into our faces by the raging winds as to threaten suffocation. The cheering repose of the elements but a moment before, had now given place to what might well be felt as the power and hoarse rage of a thousand furies; and the shroud of darkness that was in a moment thrown over us, was nearly equal to that of the moonless night. Compelled to redoubled efforts to keep our feet and make proper advance, we struggled with the tempest, though with such odds against us that we were repeatedly slipping and getting painful bruises. Mr. Kimball finding himself too much exhausted to continue this struggle on the track, we all halted in brief consultation. It was suggested that we

return to Waumbek station, an old building a half mile below us, and there try to keep ourselves from freezing by brisk exercise. Mr. Clough emphatically vetoed this as a most dangerous and impracticable proposition, saying that our only hope consisted in pushing upward with all our might.

Here we became separated: three of the party left the track, and Mr. Kimball willingly left behind his luggage in order to continue the ascent. By thus leaving the track we escaped liability to falls and bruises, but found ourselves often getting buried to our waists in snow, and forced to exert our utmost strength to drag ourselves out and advance. We repeatedly called to Mr. Bracy, who had kept on the track as we supposed, but could get no answer. The roar of the tempest overcame our utmost vocal efforts; and the cloud of frozen vapor, that lashed us so furiously as it hugged us in its chilling embrace, was so dense that no object could be seen at a distance of ten paces. Against such remorseless blasts, no human being could keep integrity of muscle and remain erect. We could only go on together a little way, and then throw ourselves down for a few moments to recover breath and strength. We had many times repeated this, when Mr. Kimball became so utterly exhausted as to make it impossible for him to take another step. He called to the others to leave him, and save themselves, if possible. The noble and emphatic "*Never!*" uttered by the manly Clough, whose sturdy muscle was found able to back his will, aroused him to another effort. The two stronger gentlemen, whose habits of life and superior physical powers gave hope of deliverance for themselves, were both immovable in the determination that our fate should be one, let that be what it must.

The situation was one of momentous peril, especially as to Mr. Kimball, whose exhaustion was now so extreme that he was wholly indifferent to the fate that seemed to impend, only begging that he might be left to that sleep from whose embrace there was left no power of resistance. Still there was forced a listless drag onward, mostly in the interests of his companions, and in obedience to their potent wills. After this sort we struggled on a few rods at a time, falling together, between each effort, to rest and gain new strength. With the wind at 70 miles per hour, and the thermometer down to 7°,—as was found after arriving at the observatory,—we came at length to "Lizzie Bourne's monument," only thirty rods from the observatory. It took more than a half hour's time to make this last thirty rods. Even the stronger ones had become wearied by their unusual exertions, and had not this been the case their progress would have been slow, for it was found absolutely impossible to force on the one who had now become unable to regard his own peril, more than a few feet at a time. He would then sink down into a deep sleep, while the others would employ the time in chafing his hands and feet, and, after a few moments, manage to arouse him and make another struggle onward.

Mr. Bracy, too, had a narrow escape. Losing his foothold on the track, he at one time fell through into a gorge beneath the trestle-work. Exhausted, bruised, and discouraged, he crawled beneath the ruins of the old "Gulf house," which were found to be at hand, thinking he would try to weather the storm there; but finding himself, in

spite of every effort, getting numb and dozy, he rallied to a new struggle, and thus saved himself.

Mr. Huntington, aroused by the arrival of Mr. Bracy, sallied out with a lantern in search of us, but found his best exertions of little avail, the storm being so fierce and thick that he could neither make himself seen nor heard beyond a few paces; and they were regarding us as probably lost, though preparing for another effort in our behalf, when we arrived.

This was perhaps the most perilous ascent of the winter, owing to the storm and darkness, especially as Mr. Kimball had been wholly unaccustomed to severe physical exertion. The ascent, under the greatest difficulties, was that of April 5, by Messrs. Clough and Cheney. The wind blew over eighty miles an hour, while the temperature was nearly at zero. They succeeded in reaching the summit on account of their superior powers of endurance. Most persons would have perished. An ascent has since been made, however, by Mr. Huntington, late in November, 1873, under circumstances still more perilous. The temperature was 17° below zero, and the velocity of the wind 72 miles per hour. It should be remembered that, at the same time with such severity of exposure upon the mountain, the weather at the base may seem favorable for the ascent.

The expedition had an early experience of the furious storms peculiar to mountain summits. Mr. Huntington writes: "There was a storm of some severity the 24th of November, when I was alone on the mountain. But the most severe storm, of all that we had, occurred on the 15th of December, and, as it was the first terrific storm since the house had been built which we occupied, we did not feel that security that we should in one that had stood the force of the storms in winters past. The other houses are of stone; ours of wood,—and, besides, presented a much greater surface to the wind than any building ever before erected on the summit. Two of the party had never been on a mountain during a winter storm, so they would be likely to describe it more vividly than a person who had witnessed many,"—as appears in the following, by H. A. Kimball:

We have had probably as severe a tornado as will visit us during the winter. The velocity of the wind was recorded at 7 P. M., and it was 92 miles per hour. After that time it was not safe to venture out with the anemometer, unless we wanted to take an

air-line passage to Tuckerman's ravine, for the wind kept increasing until towards morning, when it blew a terrific hurricane. Mr. Huntington and Mr. Clough, both having had considerable of this kind of experience, say it must have blown, at the highest point, 110 to 120 miles per hour. We expected at any moment to have the building come down about our heads, and were prepared to make an effort for our lives, having put hard-tack in our pockets, and armed with axe and saw, ready, in case we found it necessary, to cut our way out, getting also some of our thickest blankets ready for use, and preparing with considerable excitement for any emergency. The wind roared terribly, as if inspired with the power and spite of all the furies, and the wild rage was so deafening that we were obliged to shout to our utmost in order to be heard. Huntington and Clough were both very cool, although I believe they thought the chances were more than even that we should have quarters elsewhere before morning. We watched all night, waiting anxiously the effect or result of the hurricane; and, after a long night of such fearful tumult, morning brought us a little relief, by reducing the velocity of the wind to 84 miles per hour. We were duly thankful for this slight change, and at breakfast we congratulated each other on our narrow escape; for, if the building had been crushed, our chance for wishing any one a "Merry Christmas" and "Happy New Year" would have been very small; for the mercury was 15° below zero, and the barometer, the lowest recorded so far, 22.796. This remarkable fall will not happen often, but when it does we shall keep housed. The immediate danger is passed, however, and our good cover has been severely tested, and has not been found wanting in point of strength. We have more confidence in it than we had before the storm.

We continue this narrative with extracts from the journal, written by S. A. Nelson:

December 21. Forefathers' Day was celebrated by the arrival of Prof. Hitchcock, L. B. Newell, E. Thompson, F. Woodbridge, and the writer. We ascended in a rough south-west snow storm, with the velocity of the wind at 59 miles per hour. It is pleasant to be located at last, and settled down for the coming six months. It is quite a change, in one short week from busy Boston, to this out-of-the-world-up-in-the-clouds observatory. . . . There are no signs of animal life outside. Mice are plenty in the house, and it is thought that a sable has taken up winter quarters under the building.

December 23. Kimball was up first this morning, and had the first sight of as beautiful a sunrise as one could wish. It was a cold morning, the thermometer indicating 0; but we don't feel the cold as sensibly as in the lower regions. Clough and Kimball took some fine views to-day,—among them, one of the observatory, with Clough, Smith, and Nelson standing by the door. Later in the day, they took one from the roof of the hotel. They have been successful against odds, having had but three days so far suitable for work during a month's residence.

December 24. Yesterday afternoon, and late at night, a "snow-bank" lay along the south; this forenoon, snow was falling, with a temperature of —13°. At times, during

the day, the wind was as high as seventy miles an hour: consequently we were confined to the house. Mr. Smith has much to do, many messages being sent to and from the "lower regions." He sends his first regular report to Washington to-night. We have sent a press despatch of "A merry Christmas to all the world below."

December 25. There were no clouds above or around the summit. Below, and but a little lower than this peak, the clouds were dense, and covered an extensive tract of country. Through the less dense portion of the lighter clouds, the sun's rays gave a peculiar rose tint, extremely beautiful in effect. This was my first cloud view, and it was a treat beyond expectation. . . . Mr. Smith takes our four-footed friends, the sable and mice, under his especial care, and sees that they get all the waste food. They are our companions, though we see them but seldom.

January 10. The snow is nearly all off the houses and the rocks—a great change in three days' time. At 1 P. M. it was 37°. Like April it seemed;—but who knows what it will be to-morrow?

January 16. Still raining. At 11 this forenoon, Mr. Smith started out on a voyage of discovery; but it rained so hard, and the walking was so difficult, that he soon came back. Did n't stop long, however; he is too energetic a man to give up easily. So, putting on an overcoat, and otherwise prepared, he once more went out, determined to find the break in the wire, if he had to go to Littleton. Wished him good luck, not expecting to see him again for three or four days,—and he was off. But we soon heard the click, click, click of the instrument, and knew that he had found the break. In half an hour he returned: the break was at the Gulf tank. Mr. Huntington went down to the spring to-day, and brought up a pail of water. A week ago this was an Arctic region; now it is more like April in the valleys of New Hampshire.

January 17. Perfectly clear at sunset. Had one of the best views of the shadow of Mt. Washington yet obtained. The mountains, far and near, look gray now since the rains.

January 18. I have seen to-day a sea of clouds. At 10 A. M., westward from a line due north and south, as far the eye could see, the clouds presented the appearance of a frozen ocean,—the surface level and motionless, apparently, but really moving eastward, and only a little below the summit. In no direction west of a line north and south was there a glimpse of mountain or valley. Turning to the east the contrast was striking, for in this direction there was scarcely a single cloud, and the atmosphere was remarkably clear. Saco valley was never more distinct,—while the range, comprising Clay, Jefferson, and Adams, was completely hidden; but the Carter range loomed up as on a clear morning when not a single cloud can be seen, and far away the ocean was plainly visible.

January 22. Having a gale to-day, and not only a high wind, but a temperature below anything I have ever experienced before, now at 9 P. M., —34° inside the door. The wind is 80 miles, blowing steadily. At 2 P. M., wind 72, Mr. Huntington measured the velocity. He had to sit with a line around him, myself at the other end,

in-doors, as an anchor: even then it was almost impossible for him to keep his position. Temperature, —31°

January 23. The wind raged all night. The house rocked fearfully; but as we had no fear of a wreck, it did not disturb us much. Sometimes it would seem as if things were going by the board, but an inspection showed everything all right. It is a sublime affair, such a gale,—only we do not care to have it repeated too often. Nobody was hurt or scared, though there was not much sleep for our party, with such an uproar of the elements. Evidently the spirits of the mountain are angry at this invasion of their domain. Toward morning the wind ceased, and all day it has been nearly calm. The temperature outside, —43°. Mr. Huntington and myself sat up all night to keep fires going.

January 31. The most glorious sunrise this winter. To the east was a sea of clouds, somewhat broken, and much lower than usual. The protruding peaks resembled islands more than ever before. Over northern New Hampshire and Maine, and along the coast, the clouds were very dense, but their upper surface, as the sun shone across them, was of dazzling brightness, while singular forms of cirrus clouds overcast the sky. Low in the west it was intensely black, and detached masses of clouds floated along the northern horizon. For an hour after sunrise all these cloud forms were constantly changing in color,—purple and crimson, leaden hues and rose tints, almost black and dazzling white.

February 2, 10 P. M. All day the wind has been light, and it was nearly calm this evening till half an hour since, when, without any warning, the gale began, not with a rising wind, but a sudden blast that shook the house to its foundations. I said that we had no warning of its approach: we had notice of it in the falling of the barometer. A moment before the first blast, some one called attention to the quiet night, remarking that the storm would not probably reach us before morning, when the conversation was suddenly interrupted by the uproar of the elements.

February 3. We get to-day the most severe snow storm of the winter so far. The wind is north-west, the point from which our storms and hurricanes come. At no time has the temperature been higher than 5°; it was —25° this morning at 7 o'clock. Smith and myself are yet on the sick list, so all the hard work falls to Mr. Huntington. To add to the discomfort of our situation, the line failed last night, just after Smith got off the press despatch. Cold as it is, and has been all day, Mr. Huntington made six trips down the railway repairing line. His method was to find and repair a break, then run for the house, get thoroughly warmed and rested, and then out for another attempt. The last time he went to the Gulf: below there he did not dare go. So, as there is at least one more splice to make, far as any good for to-night telegraphing goes, his labors were of no avail.

February 4—9 P. M. The wind, rising toward morning, has held its own all day,—at no time being below seventy-five, and, since 8:30, acts as though it were ambitious to attain the ninety-mile standard. This has been so cold a day that we found Dr. Kane's voyages most suitable reading. At 7 A. M., —33°, and it has gradually worked down to

—40°. We have the stoves at a red heat. Ten feet from the stove, at the floor to-day, the temperature was only 12°, and at the same time was 65° in other parts of the room. . . . Find that I froze my fingers while *sawing* off a piece of pork for our "Sunday baked-beans;" was out only five minutes. It was like cutting into a block of gypsum, to saw off that piece of pork.

Midnight. Really, there is quite a breeze just now. Some of the gusts, from what we know of the measured force, must be fully up to one hundred miles per hour. In fact, it is a first-class hurricane. The wind is north-west, and, as the house is fully broadside to it, the full force is felt. At times, it seems as though everything was going to wreck. We go to the door and look out: it is the most we can do. To step beyond, with nothing for a holdfast, one would take passage on the wings of the wind in the direction of Tuckerman's ravine. We shout across the room to be heard. Now the wind suddenly lulls, and, moaning and sighing, it dies away. Then, quickly gathering strength, it blows as if it would hurl the house from the summit. The timbers creak and groan, and the windows rattle. The walls bend inward, and, as the wind lets go its hold, rebound with a jerk that starts the joints again. The noise is like rifle-firing in fifty different directions at the same moment in the room—a moment ago, close by me as I sat here leaning against the wall, now in the outer room, or up aloft, and outside as well. Then there is the trembling and groaning of the whole building, which is constant. Everything movable is on the move. Books drop from the shelves. We pick them up and replace them, only to do it again and again. We have just looked at the thermometer; find the temperature lower than at last observation,—now minus 40°. Huntington and Smith are taking hourly observations. When we hear an unusually loud report in the outer room, one goes to inspect. Nothing has given away yet.

February 5. From 1 to 2 A.M., the wind was higher than during the early part of the night. Some of the gusts must have been above 100—possibly 110. The tempest roared and thundered. It had precisely the sound of the ocean waves breaking on a rocky shore. And the building, too, had the motion of a ship scudding before a gale. At 3 A.M. the temperature had fallen to —59°,* and the barometer stood at 22.810; attached barometer, 62°. Barometer was lowest yesterday at 8 A.M., when it was 22.508, and attached thermometer, 32°.

9 A.M. Talked over the events of the past night at the breakfast table, recalling many laughable incidents, and agreeing that we rather enjoyed the night's experience than otherwise; that it was a sublime affair (having full confidence that the house would stand, the storm had no terror for us); but all things considered, were unanimous in the opinion that once in a fortnight was quite often enough for such grand displays of the storm-king's power. Of all the nights since this party came here, the last exceeds every one.

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* The Signal Service did not provide us with a spirit thermometer; consequently it is impossible to say how cold it was at this time, the instrument in use not being reliable below —38°. C. H. H.

February 6. They have put the line in order to-day, and Mr. Huntington sent an interesting press despatch. Wonder if our situation excites any comment, especially as we have held no communication with the lower world for three days.

Tuesday, February 7. A glorious sunrise, and a quiet, warm day. Temperature at 2 P.M., 62° in the sun. Change of temperature since Sunday of 121°! . . . . I have given some time this afternoon to the study of cloud formations. Days like this are so rare that we improve every opportunity for investigation. Gales, storms, hurricanes, all clear off with a north wind,—a wind gentle and soft as the south wind of the lower regions. How can this be explained? It is S. S. W. to-night, and two miles per hour,—a marked contrast to Sunday morning. Mr. Holden telegraphs from Littleton that we may expect him to-morrow.

February 8. Smith and I laid in a supply of ice, enough for three days' consumption. Are obliged to look sharp in fair weather and lay in an ample stock of ice, for it sometimes happens that we cannot replenish for several days. . . . At noon the party arrived, consisting of Messrs. Holden, Cogswell, and Clough. They received from us a right hearty welcome. They brought a large mail, and a contribution of magazines and papers. Some of the dailies are more than a fortnight old, yet we read them with as much eagerness as we do the evening paper at home. The evening has passed pleasantly. We had something to tell our friends of mountain life; and they, in return, had much to relate of events occurring since we left the region below the clouds.

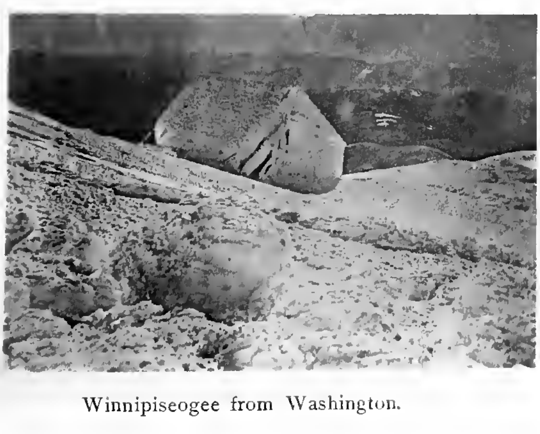
February 9, 9 P. M. Cloudy all day, wind moderate; temperature high as 26°. The cloud on the mountain so dense that it was impossible to see ten rods in any direction. It is a pleasure to have company in this out-of-the-world place; and I sincerely hope that we may be able to treat our friends to some one or more of the Mt. Washington novelties,—a gorgeous sunrise or brilliant sunset, a superior show of frost-work, or, failing in these, something in the line of hurricanes. It is a pity that they should be at the trouble of making the ascent at this inclement season, and not take back something of the experience that falls to our lot daily—something to endure, or enjoy, as the case may be. The line has been down to-day between Littleton and Concord: this time it is *not* the Mt. Washington cable. The papers say that fears were entertained for our safety during the time the line was down. Knowing better than the good people below all about the matter, we had not the least anxiety.

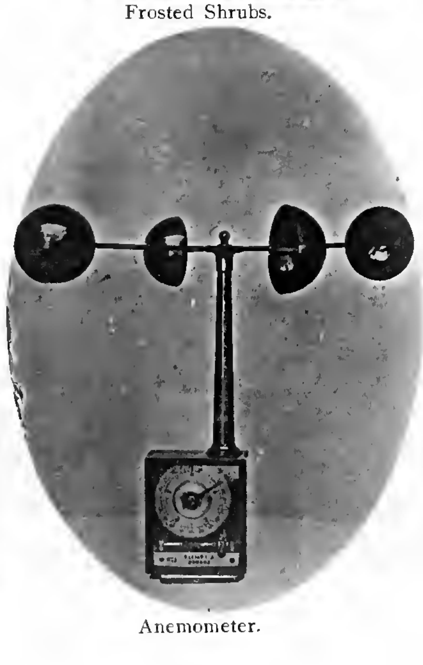
February 10. The wind high all day, 88 at 2 P. M.,—Holden having the honor of measuring its velocity, Huntington timing him. He acknowledges perfect satisfaction as regards Mt. Washington winter winds. Now, 7 P. M., the wind is rapidly rising. Been cloudy all day; a dense cloud on the mountain, charged with frost.

Midnight. About 8 o'clock the wind had worked up to the 90 mile rate, and then commenced a furious bombardment of ice from the summit and frost-work from off the house. The house shook and trembled as the fiercer blasts beat against it. Pieces of ice were driven between the bars protecting the windows, and at last, by one heavy discharge, three panes were broken. As good luck would have it, the broken lights were in the room above. The roar of the wind as it rushed through the opening was


Tip-Top House.


Frosted Shrubs.


Winnipiseogee from Washington.


Anemometer.

enough to wake a Rip Van Winkle. Huntington, Clough, Smith, and myself, were out in a moment, and after having the "hurricane" lantern twice extinguished (it is warranted to burn the brighter the higher the wind), we succeeded in nailing boards over the aperture. Still the bombardment was going on for an hour, but no more glass was broken. The supply of ammunition was exhausted by 10 o'clock, and then, though the wind was terrific, we did not mind the gale. . . . . The line failed just after Holden's *Journal* despatch went. One thing more: our friends have had the enjoyment of a very respectable if not a first-class gale. It does not seem now as if it would rise to the rank of that of December, January, or the one of last week. The temperature at 9 P. M. was —20°. Hourly observations to-day.

February 13. The party left at 11:20. Smith and I watched them going down as long as we could see them, and then returned to the house, perhaps a little envious: more silent we certainly were than usual, though this is not the first time we have lived by ourselves. Really, these few days have passed most agreeably. . . . The clouds in the morning did not present any remarkable features for this locality, but from 3 to 4:30 P. M. there was an extensive "sea of clouds." It extended from a point 60 miles north, far as the ocean east, bounded only by the horizon. This summit was alone above the cloud. It was to the eye a frozen polar ocean, here and there a lofty mountain of ice rising from the apparent dead level surface. The setting sun, throwing a silvery light along the cloud, dispelled the illusion. Perfectly clear overhead all day; our sunny day contrasts strongly with the cold, gloomy, cloudy one below. If we have much cloud here, it is not always sunshine there.

February 22. The only perfectly clear day this month; cool, the mean temperature being but 2°. These clear days, and, if nearly calm, so much the better, are the chief attractions, or rather among them, for cloud-views count in the list. On such days even the most distant mountain peaks are clearly outlined. Katahdin is to-day plainly seen, as are some mountains in Canada as distant. The view is not often good in a southerly direction; it is not to-day. The mountains belonging to this group show grandly in the bright sunlight. . . . Smith has been working on the line, and I have spent the day in writing. In such weather this is a pleasant winter residence.

Anniversary of Washington's birthday, and we had not thought of it until now! We might have raised our little flag in honor of the day,—it would have been "quite the thing."

February 26. A morning perfect as a morning of winter can well be. Clouds in the valleys,—the ocean visible for a long distance up and down the coast, and far out at sea. About 9 A. M. a heavy cloud commenced to move inland, one portion of it moving up the Saco valley. Its progress was so slow that it did not shut the Glen house in till 7 P. M.

February 28. This is one of those days which make us contented with our home. It cleared off early in the morning. Wind from 50 to 70 miles per hour. The mean temperature for to-day is 0°. The frost-work is again fine; and the house, if not a marble palace, looks like a building fashioned from purest marble,—no part of the chains, wooden braces, or finish to be seen.

March 11. The morning was so fine that we felt invited out. The snow is nearly all gone. The rocks look charming in their Alpine dress of beautiful, pale green moss lichen. We were so fortunate as to discover a fine bunch of Greenland sandwort—one in bloom. I took up some of each for house-plants, that our parlor may boast its winter garden.

March 23. This morning there was a thick stratum of clouds eastward, at a moderate elevation above the summit. By 8 A. M. it was quite dense; at 9 A. M., snow-squalls to the north-east, and the clouds gradually settling in the valleys; 11 o'clock, thick on the Carter range; by 12, clouds all about, except on the summit. By 2 P. M. the mountain was in clouds. The formation,—for I can call it nothing else,—and progress of the storm were very interesting. The clouds were at a higher elevation than has generally been the case,—cirro-stratus, color gray, uniform in density over nearly the entire field of view; thick along the south-east, east, and north-east, long before it shut down elsewhere. Evidently the lower current of the wind was from the east, while the wind on the summit was west-north-west. It was two hours from the time the Carter range shut in before the summit was enveloped. The clouds poured over Mt. Adams, and, later, over the dividing ridge between Mts. Washington and Clay. They seemed to curve, as they passed over these mountain-tops, as though the upper currents of air conformed to the irregularities of surface. When there are two strata of clouds, they unite before the snow or rain falls, as a rule, though to-day snow fell an hour previous to the clouds settling on the mountain.

April 4. All the forenoon, till 1 P. M., the summit was in a dense cloud. Suddenly it lifted, or passed off, and then we had the most gorgeous display of cloud-scenes we have yet witnessed. Eastward, masses of *cumuli* rested over the valleys and the mountains. Why not call them *mountains* of cloud? Certainly. They rise far above our level, six thousand, or perhaps eight thousand, feet higher than this peak! They conform to the heights over which they lie, and seem to envelop other mountains nearly as lofty as their upper limits. The illusion was perfect; and Mt. Washington, in comparison, was a diminutive spur or outlying peak of this great mountain range. Without ever having seen the Alps, I understood them better for having seen these cloud mountains. The sun runs high, but we know nothing of spring. It is more like winter than some of the time in March. Then there was no snow;—now everywhere there is snow and ice.

April 5. All day there has been a furious storm of snow,—at one time wind 86, and temperature low as 2°. 9 P. M., wind 60, and clear. This afternoon we were surprised by the arrival of Messrs. Clough and Cheney. They were somewhat frost-bitten, ears, fingers, and feet, and it was doubtful, for a half hour, how badly. But now they are all right, though their hands and ears are considerably swollen. It is the toughest storm in which any party has made the ascent this winter.

April 28. At 4 P. M., started down the railroad, expecting to meet Mr. Huntington and Mr. Holden. To show the changes of temperature here, in a few feet of altitude, I note my trip down to-day, and up as well. Left the house at 4:30 P. M., wind 30

miles; at the Lizzie Bourne monument, 40; at the Gulf house ruins and below, fully 60, thus reversing the order of things in regard to wind. Thermometer on the summit, 28°; frost-work forming some distance below the monument. At the Gulf tank,

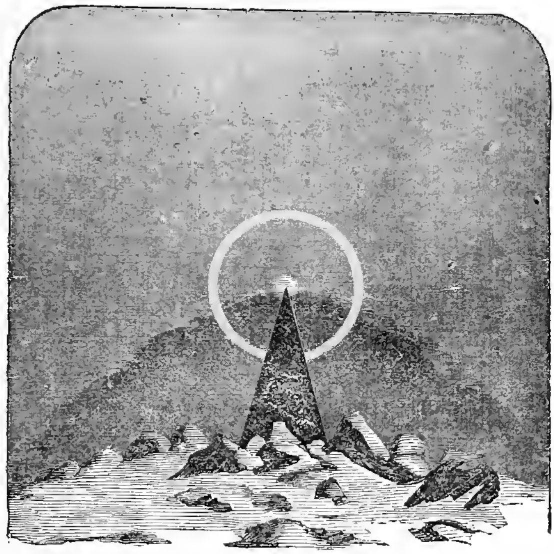


Fig. 14.—CORONA SEEN BY HITCHCOCK AND NELSON, APRIL 28.

The dark cone is shadow of observer with glory about the head. Above the foreground is the shadow of the mountain, while the large circle is the colored prism or corona resting on clouds, and partially obscuring the two shadows.

when the sun came out, as it did several times, the ice on my cap would thaw completely; then, while the cloud was passing, icicles two inches in length would form on the visor. It was difficult to walk or even stand against the wind below the Gulf house ruins. Returning, the wind was not so violent; rain as far as the plateau, where they collect water for the engine in summer; mist on the summit, with thermometer 28° at 6:50.

April 30. We have had the past month more clouds than sunshine, more snow than rain; light winds and few gales, the clouds often dense on the summit when clear below. Now only on the higher peaks, in the deep ravines, and a few places on wooded slopes is there snow.

May 2. Taking advantage of the day, Mr. Holden and myself set out for Tuckerman's ravine. Found more snow than on the 9th ult. Sunlight bright and warm there, but over Washington a dense cloud most of the afternoon. The air spring-like, as were the surroundings; little snow except at the head of the ravine, where the arch will be looked for in vain next summer, unless May makes up for the short-comings of

winter. Hermit lake really breaking up, and the stream open above. We could see the pretty cascade some distance above the lake, and hear the rushing waters, now loudly as the wind arose, now softly murmuring as it fell. Half way down the northern side, under a sheltering rock, we lunched on hard tack and sugar, drinking the pure water of a little rill which ran down among the rocks. Then for an hour we climbed the crags, getting views from many different points.

Came away at 3 P. M., too early to go home, so decided on a trip to the north-eastern spur of Washington. Passed a deep spring of excellent water, which in my jaunts I had never seen, then visited the ravine beyond. In some respects this is even more interesting than Tuckerman's, for what is wanting in extent is made up in boldness of outline, its steep, sloping northern side, and sheer precipice of two hundred feet or more on the south. Seven seconds was the time taken, by repeated trials, for a stone to reach the bottom. We propose that *Huntington's Ravine* shall be its future designation. [See frontispiece.]

May 3. Snowing all night, and cloudy all day. Mr. Smith sick,—seems no better; a rough place to be sick in;—safe from the doctors, he has that comfort!

May 4. Another tough snow-storm. . . . A pair of birds have made the house their home of late. To-day, especially, they have hardly been out. This afternoon they have sung several songs for our benefit. To-night they sit on the beam over this room, close by the flue, and we can occasionally hear them twitter, softly calling to each other.

On May 6, Messrs. Holden and Nelson visited Mt. Adams. A description of a phenomenon seen on their return is given as follows: "In ascending the cone of Mt. Washington we again got above the cloud level, and enjoyed a rare sunset scene. We also witnessed a veritable battle of the clouds. The wind, which had been very light throughout the day, had appeared to come from different directions at different points,—now from the east, in another place from the north or north-west, and again from the west or south-west. We had ascended a little distance above the Gulf tank, when we turned and observed two ghostly armies approaching each other, one from the direction of Mt. Monroe, and the other from out the depths of the Great Gulf. Noiselessly they marched onward, and the conflict came near the gap between Mts. Washington and Clay. The battle was short and decisive. Little fragments of cloud, like wreaths of smoke, were flung high in air, and there seemed a momentary indecision, but the fleecy forms from the south-west were soon fleeing before the fast gathering hosts of the east, until all were commingled in one shadowy mass."

May 7. The barometer fell 50-100ths from last night at 9 o'clock to this morning at 7 o'clock. Wind rising at 3 A. M., reaching the highest velocity at 2 P. M., which was 67,—highest recorded for some time, forcibly reminding us of the winter months. Snowing all day; the whirling, driving clouds of snow made it far from pleasant to stay out for three minutes, the time occupied in taking the force of the wind. At 5 P. M. the cloud passed off, and we could see that not the mountains alone, but the lower country as well, were "snow bound."

May 11. A wintry sky and winter scenery this morning: the sky a pale blue, and the sunshine that of December. The clouds presented an infinite variety of shades—gray, brown, and dingy black. Distant mountains showed clear cut outlines; snowy peaks of the higher mountains glisten in the morning light. Looking beyond them we see a change. The Androscoggin is broader, and its waters sparkle in the play of sunlight; the valleys are bare and brown. Last winter, the river was a silver thread; the lowlands white as are these summits now. Only these differences between a pleasant morning last December and this. Twenty degrees at 7 A. M.

Mr. Huntington expects to leave us soon. How quickly the winter has passed, spite of storms, hurricanes, and clouds,—of discomfort, and rather hard fare, and the many deprivations. Smith is still far from well. To endure, without suffering in some respect the sudden changes of weather, one needs an iron constitution; and any one that stays here should have a will equally as strong. It is hard on an invalid. I can bear testimony to that.

May 12. The last press telegram goes to-night. Nor shall we any longer have pleasant evening chats by telegraph with Prof. Hitchcock at Hanover. Smith is at the depot to-night; and the telegraph has no word for us.

May 14. The wind was high as 80, if not higher, during the night. All day, as usual, it has been cloudy, and frost-work forming. Temperature at 7 A. M. was 11°, and highest for the day, at 9 P. M., 21°. At no time was the wind lower than 46. Mr. Huntington left at 9 A. M., in the face of a 48-mile gale, and the temperature only 14°. I am anxious for his safety, and shall be till Smith returns. To-night, for the first time, I am keeping "watch and ward" on the mountain-top alone.

The winter's work is done. We trust that it has not been time and labor lost. Storms of unparalleled severity, when, for days in succession, the summit was enveloped in clouds, and the hurricanes lasted longer, and were more violent than any yet recorded in the United States, together with very low temperatures, have been a part of our experience.

Though interesting, these grand atmospheric disturbances are not the most enjoyable features of mountain life. There were mornings when the atmosphere was so transparent, and the sky so pure a blue, with not a fleck of cloud, the snowy mountain-peaks so dazzlingly white, their forms so clearly outlined and standing up in such bold relief, that they seemed the creation of yesterday; and mornings when earth and sky, forests, lakes, and rivers, and the clouds above, wore a radiance and richness of color never seen in other than mountain regions and from the loftiest elevations. There were days when the shifting views of each hour furnished new wonders and new beauties,—in the play of sunlight and changing cloud-forms,—every hour a picture in itself, and perfect in details. Sunsets, too, when an ocean of clouds surrounded this island-like summit, the only one of all the many high peaks visible above the cloud billows, all else of earth hidden from sight. There were times when this aerial sea was burnished silver, smooth and calm; and times when its tossing waves were tipped with crimson and golden fire.

Although our situation has been very much an isolated one, and the area of our little world limited, our daily life has not been without incident or void of interest,—to us, at least. But now, our work being done, we go down to the busy world once more. And though we look forward to the change with anticipations of pleasure, we half-regretfully turn our backs upon this majestic old mountain, whose cloud-enveloped summit has so long been our home.

NOTE. It is proper to add, in respect to these disconnected notes of the expedition, that this journal was kept for private reference by Mr. Nelson, with no intention or expectation of its being published. But when an extended publication of the history of the expedition was decided on, it was found desirable to use parts of the journal to convey an idea of winter life upon the mountain, and of the experiences and impressions of the party. A more connected and particular description of the meteorological phenomena, with the deductions obtained from their comparison, is separately presented, exhibiting the practical results of the expedition.

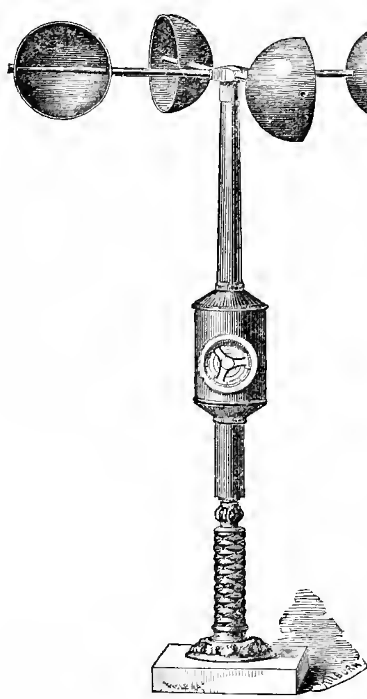


Fig. 15.—ANEMOMETER.

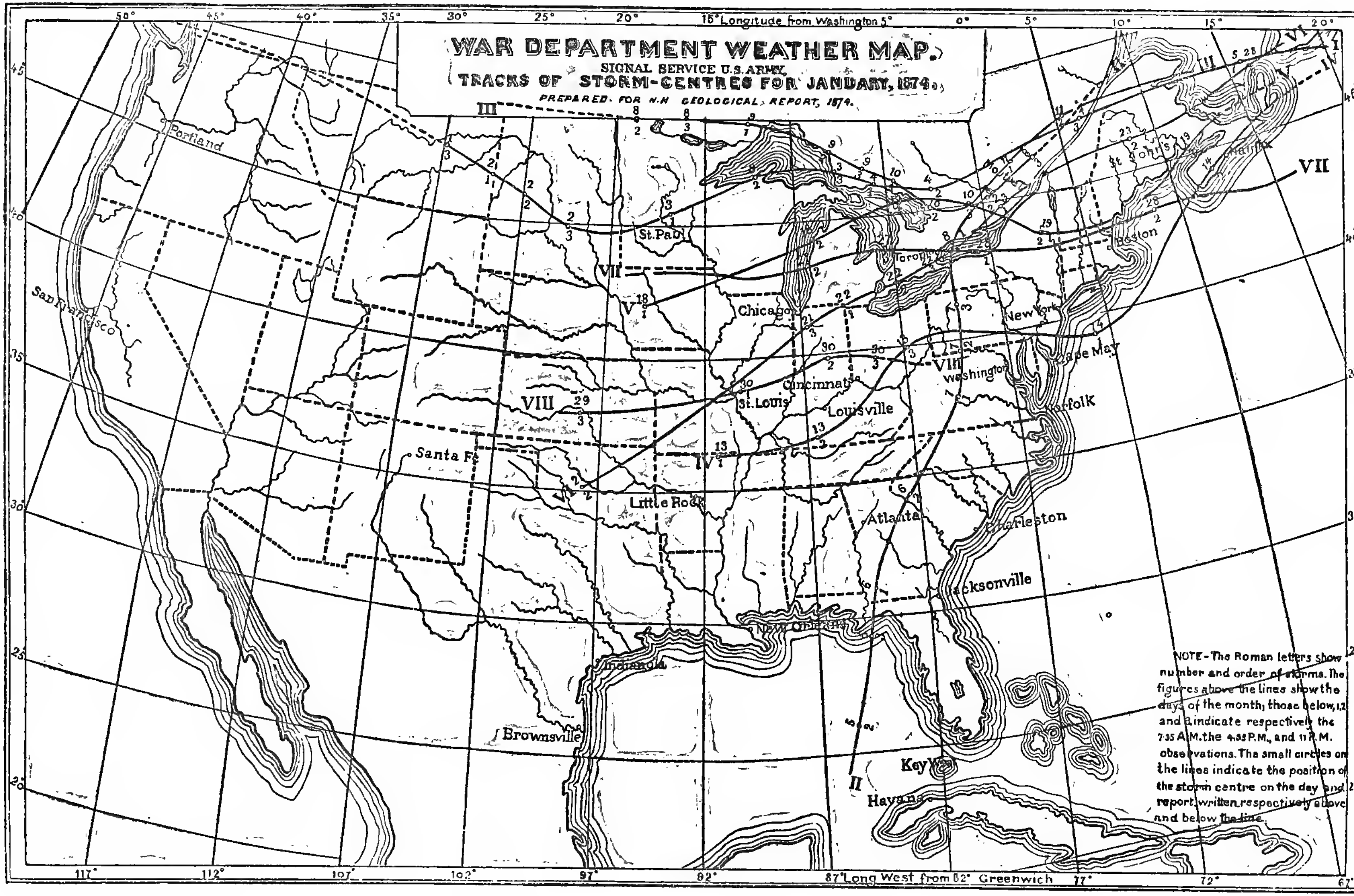
CHAPTER V.

CLIMATOLOGY OF NEW HAMPSHIRE.

BY J. H. HUNTINGTON.

THE great south-west current, that bears northward the moisture from the gulf, and renders fertile not only the great valley of the Mississippi but also the Atlantic states, the physical contour of the country and its proximity to the ocean, determine chiefly the climate of New Hampshire. Yet there is still another cause, though more remote, that may have a greater influence than we might at first suppose. The great current from the Pacific, at first moisture laden, comes in contact with the mountain ranges extending north and south. The cold summits condense the moisture, and when the current reaches the third great range it is deprived almost altogether of its moisture; yet this great current affects the climate eastward, for it is in the immediate vicinity of this mountain range that by far the greater proportion of the atmospheric disturbances are generated, the influence of which extends to the Atlantic coast, and gives us the precipitation of moisture that renders fertile our valleys, hill-sides, and mountain slopes.

After passing the third mountain range, the air, deprived of its moisture, allows the rays of the sun to pass through it, and very little heat is absorbed until they come near the surface of the earth. The thin stratum of air that contains moisture becomes heated, and at intervals it


WAR DEPARTMENT WEATHER MAP.
SIGNAL SERVICE U.S. ARMY.
TRACKS OF STORM-CENTRES FOR JANUARY, 1874.
PREPARED FOR N.H. GEOLOGICAL REPORT, 1874.
15° Longitude from Washington 5°
87° Long West from 82° Greenwich
Portland
San Francisco
Santa Fe
St. Paul
Chicago
St. Louis
Cincinnati
Louisville
Little Rock
Toronto
Boston
New York
Cape May
Washington
Norfolk
Atlanta
Charleston
Jacksonville
New Orleans
Indianola
Brownsville
Key West
Havana
Halifax
VII
VIII
II
III
IV
V
NOTE - The Roman letters show number and order of storms. The figures above the lines show the days of the month; those below, 1, 2 and 3 indicate respectively the 7.35 A.M. the 4.35 P.M., and 11 P.M. observations. The small circles on the lines indicate the position of the storm centre on the day and report written respectively above and below the line.

rises, thus creating an area of low pressure, which is the nucleus of the storm area that is carried eastward across the continent. The other great storm-centre is within the tropics. The great current of the south-east trade-wind infringes on the north-east trade-wind, and produces the cyclones that are so destructive in the West Indies and on the coast of Florida. The cyclone thus generated moves along our coast, generally with greatly diminished force, and thus we have our north-east storms. The character of these storms was first pointed out by Franklin, and the theory as to their origin has been discussed by Espy, Redfield, Maury, and others, while Prof. Joseph Henry was the first to explain the origin of the storms that move eastward across the continent. In summer, the disturbances seem to originate chiefly in the vicinity of the Rocky Mountains, while in spring, autumn, and winter, frequently, they have their origin within the tropics.

From the observations of the Signal Service, we find that there are from seven to thirteen areas of low barometer developed per month within, or pass along the border of, the United States. Of these, from one to three pass directly across or along the border of New Hampshire.

Weather Map.

The weather map on the opposite page shows graphically the tracks of the storm-centres for January, 1874. It will be seen that two of the storm-centres passed directly across New Hampshire; and it will also be seen that the storms, as a whole, are chiefly of the type that have their origin in the vicinity of the Rocky Mountains. The dotted line from the Pacific coast indicates only the probability that the storm-centre passed over that section of the country. The storms from the south usually pass along or nearer the coast than the one represented on this map. By tracing each storm-centre, a person can get some idea as to the probability of the Signal Service being able to give accurate forecasts of the weather. On account of our high latitude, sea border, our lofty mountains and narrow valleys, for our limited area the climate is exceedingly varied. On the coast, the cold of winter and the heat of summer are moderated by the breezes of the ocean. Inland, for a very few days in summer, we have more than the heat of the tropics; while on our highest mountain summits in winter, we have the climate of Greenland,—if anything, more

intense, on account of the fierce winds. In the southern portion of the state we have the trees and the birds, and we raise the grain and the fruits common in the Northern states, while on the slopes of the mountains and on the highlands in the vicinity of Connecticut lake, we have the trees and the birds, and raise only the grain and the fruits of the far north.

Notwithstanding our extremes of temperature, we have a climate far more healthful than that of most of the states east of the Rocky Mountains. The extreme heat of summer is of so short a duration that it does not produce the enervating effect of long continued heat, though of a considerably lower temperature. The bracing air of winter, and the charm of our autumn months, largely compensate for the few extremes of summer and of winter. The lassitude produced by months of heat in southern latitudes, and the extremes of cold, accompanied by fierce winds that descend with such fell swoop in the west, are both unknown; for with us winds of great velocity, accompanied by intense cold, except on the summits of our mountains, are extremely rare.

Moisture of the Atmosphere.

The climate of a country, as affecting vegetation, does not depend altogether upon the absolute amount of rain-fall during the year; but in New Hampshire, particularly, the rain must be distributed through the months when vegetation is growing, so that drouth will not check its growth. Even when vegetation is growing, there must be other conditions of moisture than rain-fall. The most important is the relative humidity of the atmosphere. This is the relative amount of moisture in the atmosphere, compared with that which it is capable of sustaining at a given temperature. Saturation is assumed as 100, and perfectly dry air as 0. The following is the absolute amount of moisture at the given temperatures.

Degrees—F.	Weight in grains—Troy.
30	2.04
50	4.08
70	7.99
80	10.94

Suppose the temperature is 30°, and the absolute amount of moisture in the atmosphere is 2 grains, then there is half the amount present that

the atmosphere can sustain: hence the relative humidity is 50 per cent. Now, if the temperature rises just above 70°, and the amount of moisture is not increased, there is only one fourth the amount of moisture that the atmosphere can sustain at that temperature; hence the relative humidity is 25 per cent. If, on the other hand, the temperature falls to 30°, there is more moisture than the atmosphere can sustain, and it is precipitated. The air feels moist or dry, not from the absolute amount of moisture present, but from its relative humidity. If the per-centage is small, the moisture evaporates rapidly from the earth and from vegetation, as well as from everything containing moisture. The opposite effect is seen on the approach of rain. After a drouth, water is seen where there had been none for weeks; and the partially withered leaves assume their natural shape,—so much so that we should scarcely know that they had been affected by a drouth: and all this before a drop of rain has fallen. Why? Because the air is approaching saturation, and moisture is no longer evaporated from the earth and vegetation.

The vapor of water diffused through the air is an obstruction to the free passage of the heat of the sun, and also prevents the sudden radiation of the heat that has been absorbed by the earth. "This," says Buchan, "is undoubtedly one of the most important and conservative functions of the invisible moisture of the atmosphere. For if the moisture was drained out of it, and its diathermacy thereby rendered complete, the sun's rays would burn up everything by their intolerable fierceness;" and during the night the escape of heat by radiation would be so rapid that, ere the sun appeared again, everything would perish that a freezing temperature could kill. We see the effect of the want of moisture frequently in New Hampshire, in the extremely hot days and cold nights that invariably accompany a long drouth.

Effect of Forests.

How far the removal or renewal of forests affects our climate, is something in which every one is interested. From the data that we have, it may be impossible to generalize to any great extent; yet there are some things that we can learn from the observations that have been made. While it is stoutly contended that there has been no decrease in the annual amount of rain-fall in the eastern part of the United States, there

are facts that show that forests have a great influence on the climate,—if not on the annual rain-fall, yet on its distribution during the months of the year and the hours of the day.

In the central and southern portion of New Hampshire, the hay crop is frequently cut short by drouth, while in the northern portion of the state, often the same year, the hay crop is above the average; yet the annual rain-fall is less in the northern than either in the central or southern part of the state. But in the north there are abundant forests; and the rain is distributed through the months when it is needed for the crops to grow and mature. The effect of the diminution and increase of vegetation is shown in the well known facts in regard to Lake Tacarigua, Venezuela. During the last thirty years of the past century, it was found to be gradually drying up; but when the valley of Aragua was devastated by war, the country, by the rapid growth of vegetation, was soon covered with forests; and it was observed by Boussingault that the water of the lake had risen so that it covered much of the country that was formerly cultivated.

The gradual rise in the height of the water of the Great Salt lake, in Utah, at the rate nearly of a foot per year, and the gradual increase in rain-fall more than three inches per year since the country has been cultivated,—and there has been a great increase of vegetation on account of irrigation,—is an important example, as showing the effect of the increase of vegetation.*

The preservation of the vegetation on our mountains is of great importance, not only in modifying the distribution of rain, but also in moderating the extremes of cold in winter.

Our mountains, especially the higher summits, except where it has been destroyed by fire, are covered to a considerable depth by peat formed chiefly from moss and lichens. Now it has been found by experiment "that peat moss can absorb more than twice its own weight of water, dry clay nearly its own weight, dry earth, or garden mould, more than half its own weight, and dry sand a little more than a third of its own weight. With equal times of drying, under the same circumstances, peat moss lost two thirds of all the water it contained, clay and earth more than three

* Monthly Reports of the Department of Agriculture.

CLIMATOLOGY
OF
NEW HAMPSHIRE

Chart 1.

——Lines of Equal Annual Temperature.

BY J. H. HUNTINGTON

fourths, and sand more than nine tenths." Farmers can determine the capacity that different soils have for retaining moisture, by taking two boxes, filling each with a different kind of soil, and pouring an equal quantity of water on each, and then suspending each of the boxes at the end of a balance, so adjusted that the bar shall be horizontal. Then, if the soils are unequal in their capacity for retaining moisture, one box will soon rise above the level of the other. This experiment was first performed by D. Milne Horne. When a mountain has been denuded of its forests and vegetable mould, the rain that falls upon it flows immediately into the streams, and is carried to the ocean; then, before another rain, the streams are dried up, the rivers are greatly contracted, and the next rain causes a freshet;—so we have a succession of drouths and floods. On the other hand, vegetable mould retains the moisture, and it is gradually evaporated, a high relative humidity is maintained, springs gush forth from the slopes of the mountains, the streams are full, but not to overflowing, and a slight change in the temperature causes rain to fall in gentle showers.

There is one marked feature in regard to the mountains in New Hampshire that have been burned, namely, the fact that the fire has, in general, spread only over their eastern slopes, and when it has reached the summits it has extended but a short distance down the western slopes, showing that the moisture-bearing currents of wind come from the west or south-west. Although it is of great importance that the mountains should be covered with vegetation, yet it is of no less importance that there should be a certain amount of forest over the entire country, and this amount should be at least thirty per cent. of the whole area. In some parts of the state the area covered by forests is much less. The general effect of forests on temperature is to make the nights warmer and the days cooler, and to moderate the extreme heat of summer, making it less intense, and the cold of winter less severe. In New Hampshire, during the winter, in calm, clear weather, the cold is more intense, or, at least, the thermometer goes lower in the valleys than on moderate elevations, or even on the summit of Mt. Washington. As the stratum of air in contact with the earth often becomes colder by contact, and as the cold air is heavier than the warmer currents, the cold air flows down the valleys like currents of water. Hence in the Connecticut and

Merrimack valleys, where these currents converge and become united, the cold is the most intense. Where the mountain slopes and valleys are wooded, the flow of these cold currents is greatly impeded. In windy and stormy weather there is, however, a gradual decrease of temperature according to the height. This decrease, comparing the observations at Hanover with those on the summit of Mt. Washington, is one degree for every three hundred and fifty-four feet; but observations continued for a series of years might greatly modify this; or, if we make the comparison at different seasons of the year, we find that the decrease, taking the monthly mean, is one degree for every five hundred feet in January, while it is the same in May for only two hundred and eighty-four feet.

Charts and Diagrams.

In order to present clearly the leading features of the climate of New Hampshire, we have prepared several charts and diagrams. These are chiefly the results of observations taken under the direction of the Smithsonian Institution.

On Chart I, we have traced the yearly isothermal lines. In the vicinity of Manchester there is a small area where the yearly mean, 48°, is greater than in any other part of the state. The observations extend over a period of fourteen years; hence, they ought to give at least an approximate average. An extended curve of 47°, of which Manchester is the centre, lies some five miles beyond the first, and forms an entirely isolated area. In contrast with this comparatively warm area, we find directly west an island of cold with the isotherm of 42°, occupying Dublin, Nelson, Stoddard, and parts of the adjoining towns. The isotherm of 46° begins at the state line in New Ipswich, runs northward, then turns south of east, crosses the Merrimack at Thornton's Ferry, and strikes the coast at Portsmouth; thence it is deflected northward in a great curve that passes above Lake Winnipiseogee, and returns to the coast at the mouth of the Piscataqua river. The isotherm of 45° passes through Dover, runs northward near the state line, and crosses into Maine from Effingham; the other end of it begins at South Charlestown, is deflected southward through Francestown, then runs northward nearly parallel with the Merrimack, passes around Newfound lake above Squam, thence through Tamworth, Madison, and Eaton, connecting with the other part of it in


CLIMATOLOGY
OF
NEW HAMPSHIRE.
Chart 2.
By J. H. Huntington.
Lines of Equal Summer Temperature.
Lines of Equal Winter Temperature.

Maine. The isotherm of 44° on the west, is a sharpe curve beginning at North Charlestown, and it has its further limit in Danbury. On the eastern border of the state there is a short curve on the Saco in Conway. The isotherm of 43° is similar in shape to that of 44°, but is some ten miles northward.

The isotherm of 42° begins on the Connecticut in Plainfield, and extends eastward, but is soon deflected northward, passes above the White Mountains, through Randolph, Gorham, and Shelburne. The isotherm of 41° is just below Hanover. Westward in Vermont it is deflected southward; but in New Hampshire it is nearly parallel with 42°, except that from Lisbon a branch goes almost directly north to Lunenburg, Vt. The isotherm of 40°, the lowest mean average in the settled portions of the state, begins near North Stratford, and probably extends eastward to Umbagog lake. As we ascend the mountains the mean annual temperature decreases rapidly, so that on the summit of Mt. Washington we have an isotherm of 25°.

Chart II. Referring to chart II, we have isotherals, or lines of equal summer temperature; and isochimenals, or lines of equal winter temperature. For the isotherals, we have a small area about Manchester, included within the line of 70°; there is also an isotheral of 70°, extending along the northern border of Lake Winnipiseogee, thence through Ossipee to the line of Maine. The isotheral of 69° is below Rochester, and there is a more extended area of the same through Tamworth, Madison, and Eaton. The isotheral of 68° corresponds with the isotherm of 47°. The curve of 67° is the most variable of all the isotheral lines.

It begins at the Connecticut, near Claremont, is deflected southward to Francestown, then northward to Barnstead, then southward again as far as Exeter, when it turns north and passes between Dover and Great Falls. The curve of 66° begins on the coast near Portsmouth, and passes up the Piscataquis to Dover, where it is deflected eastward.

The isotheral of 65° passes up the river from Hanover, thence up the Ammonoosuc,—makes a sharp curve to the Connecticut, at Lancaster, then runs through Randolph, Gorham, and Shelburne; that of 64° runs through Stoddard, Nelson, Dublin, and Peterborough; that of 63° begins in North Littleton, goes northward through Lunenburg, Vt., and then is deflected eastward and across New Hampshire, near the Grand Trunk

Railway. The isotheral of 62° is in the towns of Colebrook, Dixville, and Errol; and that of 47° touches the top of Mt. Washington.

The general direction of the isochimenal lines are the same as those of the isotheral. We have an island of cold on the line between Cheshire and Hillsborough counties, a warm area in the vicinity of Manchester, a gradual increase of the cold inland from the ocean at Portsmouth, and the same deflection northward,—but not to so great a degree,—of the lines beginning at the Connecticut. The marked conformity of the isochimenals of 19°, 17,° and 16°, with the isotherals of 65°, 63°, and 62°, is quite remarkable.

Chart III. We have here represented the entire annual aqueous precipitation. The area of greatest precipitation is in the central portion of the state, in the vicinity of Newfound lake, and it extends north at least as far as Ashland, and southward probably as far as Franklin. The rain-fall in this area, including melted snow, is 46 inches. There is an area of 45 inches from Hooksett southward toward the state line, and the table would give us a small area in the vicinity of West Enfield; but, as there seems to be some doubt as to the accuracy for that locality, we have omitted it on the chart. In the south-west part of the state, below a line from Claremont and extending to a point just north of Concord, there is a large area where the precipitation is 43 inches. There is an area of 42 inches north of Claremont, perhaps ten miles in width, extending to the Merrimack river, thence northward along the west side of Lake Winnipiseogee, when the area widens so that it includes almost the whole portion of the state north of the lake to a line above the Grand Trunk Railway. In the north part of the state, above 42, there is an area of 41 inches extending across the state, and having a width of about twenty miles. There is another small area of 41 inches, extending from Bath in a curve southward as far as Plainfield. Between this and the Connecticut, embracing a part of Orford, Lyme, and Hanover, there is an area where the precipitation is only a little more than 40 inches. Also, the whole portion of the state north of Stratford is included in the area of 40 inches. On the sea-coast, at least in the vicinity of Portsmouth, the rain-fall is less than in any other part of the state, being 35 inches,—but it increases as we go inland. At Dover there are 36 inches, and at Wolfe-borough 38. Since the distribution of rain-fall depends in a measure on

CLIMATOLOGY
OF
NEW HAMPSHIRE
Chart 3.
Mean Annual Rain-Fall.
BY J. H. HUNTINGTON.
EXPLANATION.
The figures express the mean amount of inches of rain falling annually in the several areas indicated by different colors.
35 41
36 42
37 43
38 44
39 45
40 46

the changes of temperature, to this may be due the increase inland from the ocean.

The following record shows the time of the closing and opening of some of our lakes. That of Winnipiseogee is as follows:

Closed with Ice.	Clear of Ice.
1867—December 19.	1868—April 10.
1869—January 19.	1869—April 28.
1870—January 23.	1870—April 21.
1871—January 14.	1871—April 10.
1872—January 3.	1872—May 4.
1873—December 17.	1873—May 4.

Umbagog lake generally closes about November 15;—was entirely clear of ice, April 28, 1871; May 10, 1872; May 11, 1873.

Connecticut lake closes earlier and opens later, though the figures given to me, but not reproduced, are not exact.

The Phenomena observed on Mts. Moosilauke and Washington.

In the summer of 1869, I proposed to Prof. Hitchcock to occupy the summit of Mt. Washington the following winter, for the purpose of taking meteorological observations. He heartily approved of the undertaking, and made an effort to secure a building on the summit of that mountain. In this, however, he failed; but he did obtain permission for me to occupy a building on the summit of Moosilauke. In late autumn, preparations were made, and on the last day of the year of 1869, with Mr. A. F. Clough as photographer, I ascended this mountain, and remained there during the January and February following. The expedition was carried out chiefly at my own expense. We found out many things that were novel and interesting, and some that were new to science. The beautiful frost-work of our mountain summits was here for the first time photographed and described; and we experienced winds of greater velocity than had ever before been measured.

Our observations here made us still more desirous of spending a winter on Mt. Washington. This we were able to do the following winter, through the coöperation of Prof. Hitchcock, Mr. S. A. Nelson, the U. S. Signal Service, and the seventy-five individuals and firms, besides railroad corporations, that furnished material aid. The mountain has since been occupied by the Signal Service, and last summer a building was erected for the use of the observers.

Frost-Work.

The frost-work is the most remarkable phenomenon of our mountain summits. It is difficult to convey, in words, any idea of its wonderful form and beauty. It was not easy, at first, to understand how it could be formed; but we are able now to give a plausible theory to account for this the most extraordinary of all the handiwork of Nature. It is very rarely formed except when the wind is at some point between north and west, and only when there are clouds on the mountains. It begins with mere points on everything the wind reaches,—on the rocks, on the railway, and on every part of the buildings, even on the glass. On the south side of the buildings and the high rocks it is very slight, as the wind reaches there only in eddying gusts. When the surface is rough, the points, as they begin, are an inch or more apart; when smooth, it almost entirely covers the surface at the very beginning; but soon only a few points elongate, so that on whatever surface it begins to form, it has soon everywhere the same general appearance, presenting the same beautiful, feathery-like forms.

> "Thus Nature works, as if defying art;
> And in defiance of her rival powers,
> Performing such inimitable feats,
> As she, with all her rules, can never reach."

In going up Mt. Washington, we do not see the frost-work until we get above the present limit of the trees. It is nearly a mile above before it is seen in its characteristic forms, and it is only immediately about the summit that it presents its most attractive features. On all our mountains north of latitude 43° 50′, that are more than thirty-five hundred feet in height, it can be seen extending down to a certain line, and this line extends along the whole mountain range. Everywhere it appears to be at the same elevation. We notice that it always forms towards the wind, never from it; and the rapidity with which it forms, and the great length of the horizontal masses, are truly wonderful. On the piles of stones south of the house, the horizontal masses are sometimes five and six feet in length. On the southern exposures, instead of the frost-work, especially on the telegraph poles by the railway, there are only masses of

pure ice, which have always a peculiar hue of greenish blue; and there is a striking contrast between this and the pure white of the frost-work on the side opposite. When the thermometer ranges from 25° to 30°, and the wind is southward, ice often forms to the thickness of a foot or more on the telegraph poles near the summit. These icy masses are formed evidently by the condensation of the vapor of the atmosphere. The frost-work is also formed by the condensation of vapor, but, besides the vapor, the air must be filled with very minute spiculæ of ice. As the vapor condenses, these are caught, and thus the horizontal, feathery masses are formed. This accounts for the facts that we have observed, namely, that it forms when the wind is northward, and always towards the wind.

Fig. 16 will give a general idea of the appearance of the Tip-top house when the frost-work has formed to a thickness of two or three feet on the building and the rocks.

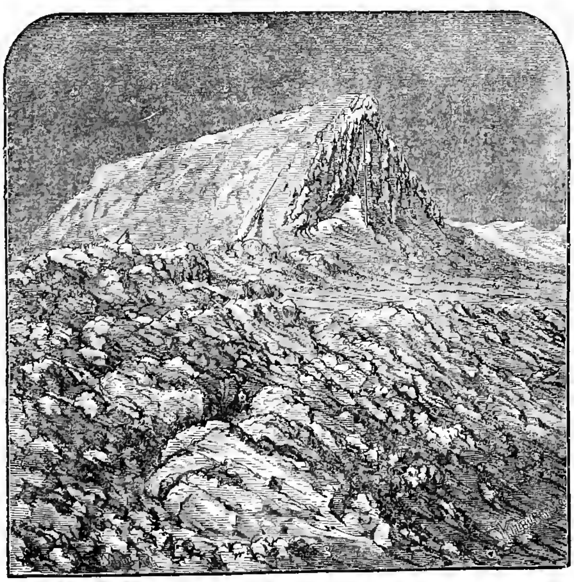


Fig. 16.—TIP-TOP HOUSE IN WINTER.

The beginning of the frost-work is shown in the accompanying heliotype entitled Frost Feathers. Here they are formed on the surface of a rock. The longest points are ten inches in length, and each presents

serrated and feathery edges. This view was almost the very first ever taken of this peculiar form of snow-ice; and had it not been for the self-denial of my late friend Mr. A. F. Clough, and his intense love of the grand and beautiful in nature, it is probable that many years would have elapsed before another artist would have had the inclination, much less the courage, to encounter the difficulties and dangers that presented themselves to a person who contemplated spending a winter on the summit of one of our highest mountains.

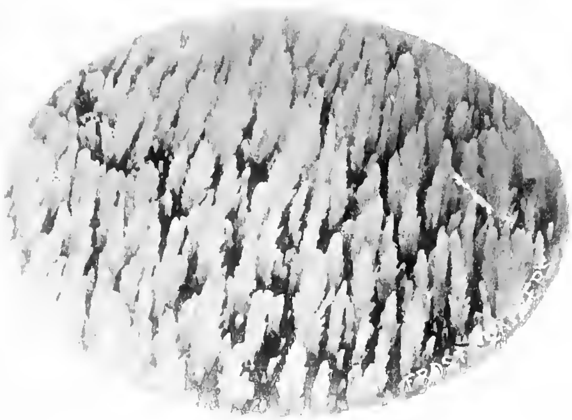
In the illustration entitled Snow-ice, the frost feathers are elongated, and form immense feathery masses two or three feet in length. On account of the boards being loose, it has fallen off from the side of the building; but this is an advantage, since the corner of the building can be seen, and one can get a better idea of its form and length. The view was taken on the summit of Mt. Washington by Mr. B. W. Kilburn, in 1872, who, by his perseverance and skill, has made our Alpine scenery known to tens of thousands who have never visited the mountains.

The Weather at High Altitudes.

As to the extraordinary weather on our mountains in winter, the following description is a typical illustration of two days on Moosilauke:

On the first day of January the sun rose clear. We were above the clouds, and a grander spectacle one does not often behold. The clouds seemed to roll and surge like the billows of the ocean. They were of every dark and of every brilliant hue: here they were resplendent with golden light, and there they were of silvery brightness; here of rosy tints, there of sombre gray; here of snowy whiteness, there of murky darkness; here gorgeous with the play of colors, and there the livid light flashes deep down into the gulfs formed by the eddying mist, while

"Far overhead
The sky, without a vapor or a stain,
Intensely blue, even deepened into purple
When nearer the horizon it received
A tincture from the mist that there dissolved
Into the viewless air. . . The sky bent round
The awful dome of a most mighty temple,
Built by Omnipotent hand for nothing less
Than infinite worship. So beautiful,
So bright, so glorious! . Such a majesty
In yon pure vault! So many dazzling tints
In yonder waste of waves."




SNOW
ICE

But above all these clouds, these flashes of light, this darkness, rises in stately grandeur the summit of Mt. Washington, "sublime in its canopy of snow;" and Lafayette, with a few peaks of lesser altitude, glitters in the bright sunlight. As the sun rises higher, the picture fades away, and the whole country is flooded with light. Did this grandeur, this magnificence, this grand display of lights, of shadows, and shades,—these clouds, so resplendent, so beautiful,—portend a storm? In the evening the wind changed to the south-east, and increased in velocity.

At daylight, on the second, it was snowing. This soon changed to sleet, and then to rain; and, at 8 A. M., the velocity of the wind was 70 miles per hour. At 12, there was a perfect tempest. Although the wind was so fearful, yet Mr. Clough was determined to know the exact rate at which it was blowing. By clinging to the rocks he succeeded in reaching a place where he could expose the anemometer, and not be blown away himself. He found the velocity to be 97½ miles per hour,—the greatest velocity, until that time, ever recorded. When he reached the house he was thoroughly saturated, the wind having driven the rain through every garment, although they were of the heaviest material, as though they were made of the lightest fabric. During the afternoon, the rain and gale continued with unabated violence. The rain was driven through every crack and crevice of the house, and the floor of our room was flooded. So fierce was the draught of the stove, that the wind literally took away every spark of fire, leaving only the half-charred wood in the stove; and it was with the greatest difficulty that we succeeded in rekindling it. During the evening, the wind seemed to increase in fury; and although the window was somewhat protected, yet nearly every glass that was exposed was broken by the pressure of the gale. As the lights were broken, the fire was again extinguished; and even my hurricane lantern was blown out as quickly as if the flame had been unprotected. Darkness, if not terror, reigned; but calmness, with energy, are requisites for such an occasion, and, fortunately, they were not wanting now. Our necessities quickly showed us what to do. By nailing boards across the windows, and by the use of blankets, we stopped the openings the wind had made. After 9 P. M. there were occasional lulls in the storm, and by 12 it had considerably abated, at least enough to bring on that depression that naturally succeeds a period of intense excitement;—so we willingly yielded ourselves to sleep, to dream of gentle zephyrs and sunny skies.

Although as a rule rains in winter are not common on the summits of our high mountains, yet observations thus far show that every third winter they may be quite frequent.

As already indicated, the clouds are often spread out in a thin stratum over a large area, and we look forth upon an illimitable sea of mist glittering in the sunlight, while every peak, except that on which we stand, is concealed by clouds. So it is not uncommon for it to be a dark day in the valleys, while on the summit of the mountain we are in the bright

sunlight. Sometimes the clouds are two thousand feet below the summit of Mt. Washington;—in that case, innumerable mountain peaks protrude, and seem like islands in an ocean bounded only by the sky. The formation and the dissolving of clouds is an interesting feature. It often happens that the whole country westward is covered with clouds, but when they have passed the ridge running directly south from Mt. Washington, they are instantly dissolved, never passing a certain point, although moving at the rate of fifty or sixty miles per hour, when that point is reached. In spring and summer, instead of these horizontal layers, the clouds assume cumulose forms, and from the mountain they can be seen rising vertically thousands of feet in an incredibly short space of time. During the steady cold weather of winter, the upper clouds were never seen to move except in the same direction as the wind on the summit of the mountain.

Wind and Rain.

Of all phenomena, the wind is the most terrific. Usually during periods of storm, the wind increases steadily in velocity until it reaches its culmination: then there are lulls, at first only for an instant, and these continually lengthen until the storm ceases. The greatest velocity that has been measured is 140 miles per hour; and during one night the mean of four observations was 128 miles. The most remarkable fact in relation to the wind is the great velocity on the summit when there is a calm at the base. One observation shows that there was a wind of 96 miles per hour on the summit, when, at the depot of the Mt. Washington Railway, 2,677 feet below, there was not wind enough to move the anemometer. The observations were taken, under the direction of the War department, during the month of May, 1872, at 7 A. M., 9 A. M., 12 M., 4 P. M., and 9 P. M.

In general, winds of very great velocity are usually limited to winter, and to the time when there are clouds on the mountain. The prevailing winds for the entire year are west and north-west. It is a noticeable fact that, while the northerly and westerly winds have a much greater velocity on the summit than below, the southerly winds have frequently a greater velocity five hundred or a thousand feet below than on the summit. In Fig. 17, the curve represents the velocity of the wind. Fig. 18 shows

the rise and fall of the barometer. The correspondence between the two is very striking, especially during periods of great disturbance.

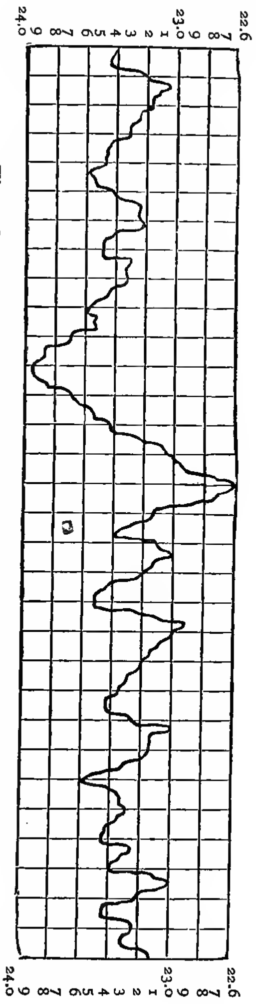


Fig. 18.—HEIGHT OF BAROMETER CORRECTED FOR TEMPERATURE.

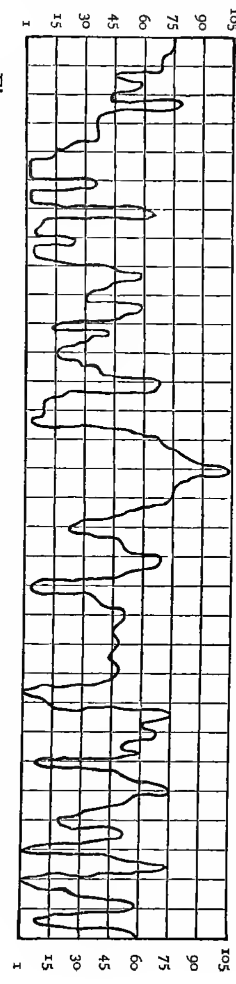


Fig. 17.—DIAGRAM SHOWING VELOCITY OF WIND IN MILES PER HOUR,—DEC. 1870.

AQUEOUS PRECIPITATION.

The observations for one year give the amount of aqueous precipitation as 55 inches, and it is confined mainly to summer and autumn,—the entire precipitation for winter and spring being given as only about eight inches, leaving 47 inches for summer and autumn. There is no means of determining the actual amount of frost-work and snow, but we know that the

snow-fall is very slight during autumn and winter, the snow-cloud being below the summit; but in spring, when showers become frequent in the valleys, there are invariably heavy falls of snow on the mountain. During a thunder-storm in April, when the thunder could be heard and the lightning seen, we were having one of the thickest snow-storms of the season.

Nearly all the optical phenomena seen elsewhere on mountain summits have been observed on Mt. Washington. Rainbows, with three supernumerary bows, have been seen for hours on the clouds; coronas, of large and small dimensions; anthelia or glories of light, the prismatic circles surrounding the shadow cast far out on the clouds; halos, and parhelia. The spectre of the Bröcken, though rare, was seen by Mr. S. A. Nelson.

Diagrams.

Diagram I shows the fluctuations in the annual rain-fall in the Atlantic states,—Maine to Maryland,—from 1805 to 1867. From the fluctuations as shown in this diagram, there are groups of years of unusual amount of rain, followed by groups of years of drouth; and, on the whole, it indicates an increase of rain. The figures on the left are the per-centage of the mean amount.

Diagram II shows the fluctuations in the annual rain-fall in the upper Connecticut valley, from observations taken at Lunenburg, Vt. This shows similar groups of years. An unusual amount of rain-fall does not necessarily imply that it was distributed throughout the year, so that there was no drouth in summer; for, while the amount of rain in 1871 was above the average, yet the summer of that year was regarded as very dry.

Diagram III shows the fluctuations in the annual snow-fall at the same locality, and by the same observer, as in Diagram II. The fluctuation, however, is greater than in the rain-fall; for the greatest amount, 167.5 inches, is more than twice as much as the mean, 83.1 inches, and the least amount, 41 inches, is less than half the mean; yet there are similar groups of years, though at no time does it show more than three consecutive years, when the amount was greater than the mean.

Diagram IV shows the annual fluctuations in rain-fall at Lake Village from 1857 to 1873. The observations were taken under direction of the Lake Company.

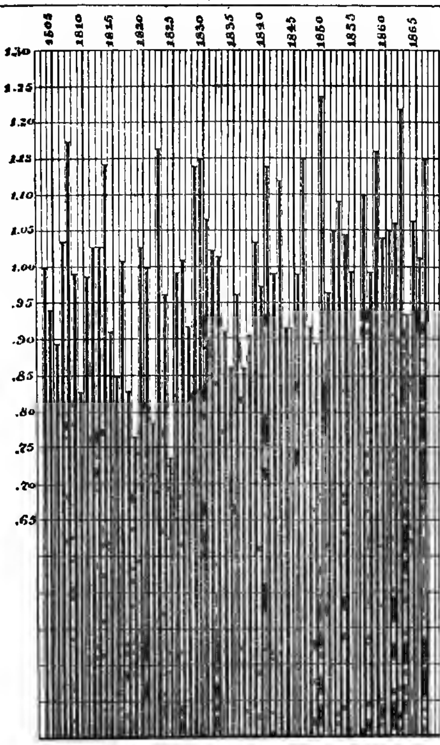


DIAGRAM I.
Fluctuations in Annual Rainfall on the Atlantic Sea-coast, Maine to Maryland; from Smithsonian Rain Table, by C. A. Schott.

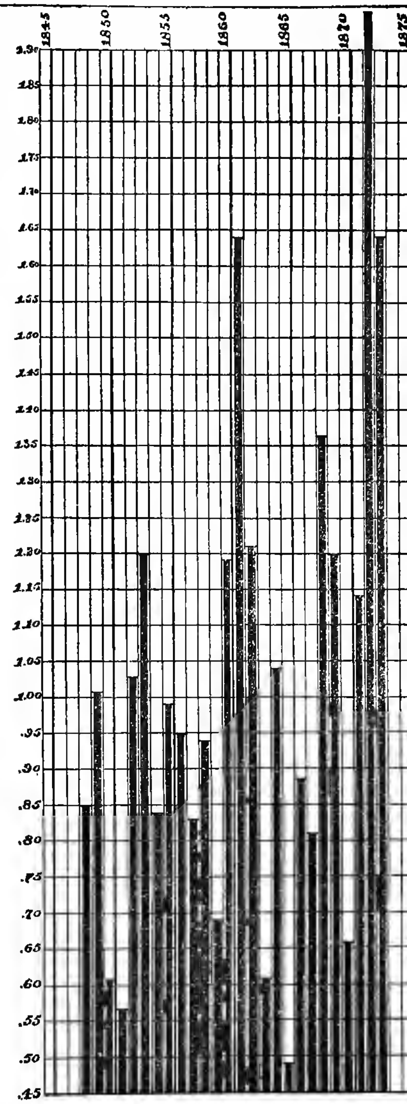


DIAGRAM III.
Fluctuations in Snowfall of the Upper Connecticut Valley; from Observations by H. A. Cutting, M. D., Lunenburg, Vt.

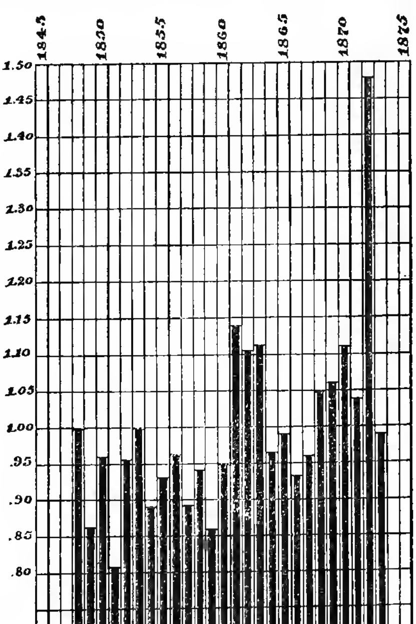


DIAGRAM II.
Fluctuations in Annual Rainfall of the Upper Connecticut Valley; from Observations by H. A. Cutting, M. D., Lunenburg, Vt.

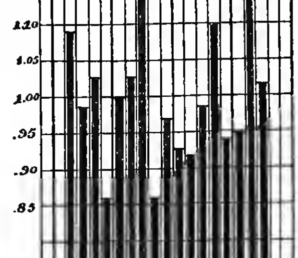


DIAGRAM IV.
Fluctuations in Annual Rainfall at Lake Village; from Observations by the Winnipiseogee Lake Company.

Diagram V is a comparison of the extreme maximum and minimum temperatures of the 7 A. M., 2 P. M., and 9 P. M. observations at Claremont and Stratford for 1867 and 1868. These places were selected for comparison, since Claremont is the most southern point in the Connecticut valley where observations have been taken, and Stratford the most northern. It is noticeable that, while the minimum of Stratford is less than at Claremont, the maximum is greater at Stratford than at Claremont. This is the general rule, though there are exceptions to both.

Diagram VI is a comparison of the monthly mean temperatures of Exeter, Claremont, and Stratford for 1864. It will be observed that, in the extreme maximum and minimum, the difference is greatest in winter and least in summer; but in the monthly mean, that the difference between Claremont and Stratford is greatest in summer and least in winter.

Diagram VII is a comparison of the monthly mean temperatures of Mt. Washington and Lunenburg, Vt.

Diagram VIII is a comparison of the maximum and minimum temperatures at Exeter, Manchester, Claremont, North Bridgeton, Me., and St. Johnsbury, Vt., during the cold period of January, 1861.

Diagram IX is a comparison of maximum and minimum mean temperatures for the cold period of January, 1871, of Mt. Washington, Tamworth, Contoocookville, Stratford, and Whitefield.

Diagram X shows graphically the difference in the velocity of the wind at the station on the summit of Mt. Washington, and a station at the depot of the Mt. Washington Railway, 2,677 feet below the summit. The figures on the left and right are miles per hour.

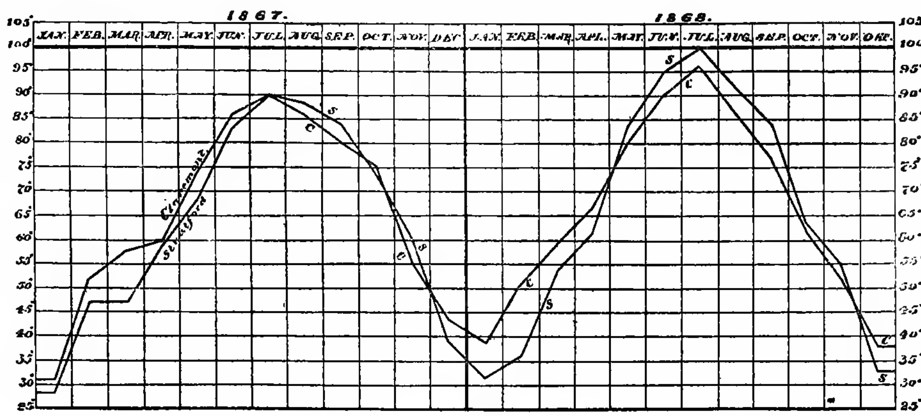


DIAGRAM V.-A.

Maximum Temperature at Claremont and Stratford; 1867 and 1868.

DIAGRAM V.-B.

Minimum Temperature at Claremont and Stratford; 1867 and 1868.

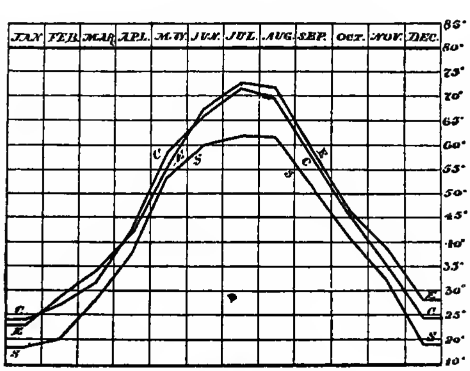


DIAGRAM VI.

Mean Temperature of Exeter, Claremont and Stratford; 1864.

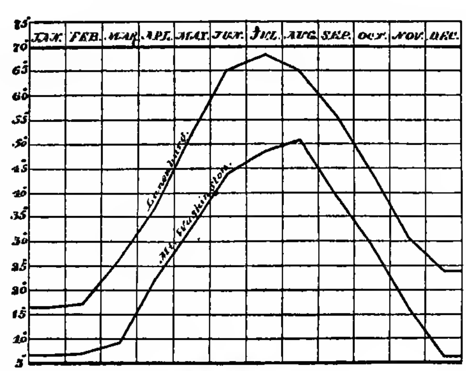


DIAGRAM VII.

Mean Temperature of Mount Washington and Lunenburg, Vt.

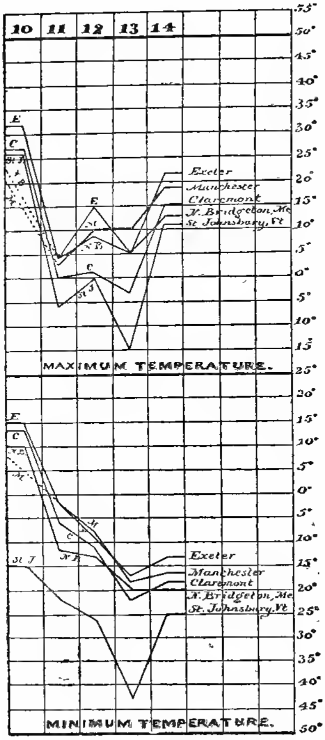


DIAGRAM VIII.
Cold Period ; Jan. 10-14, 1861.

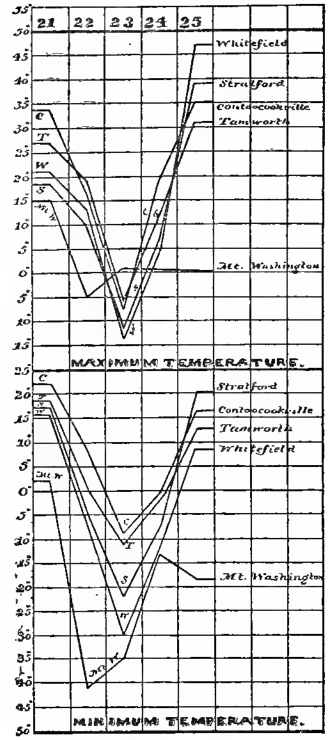


DIAGRAM IX.
Cold Period ; Jan. 21-25, 1871.

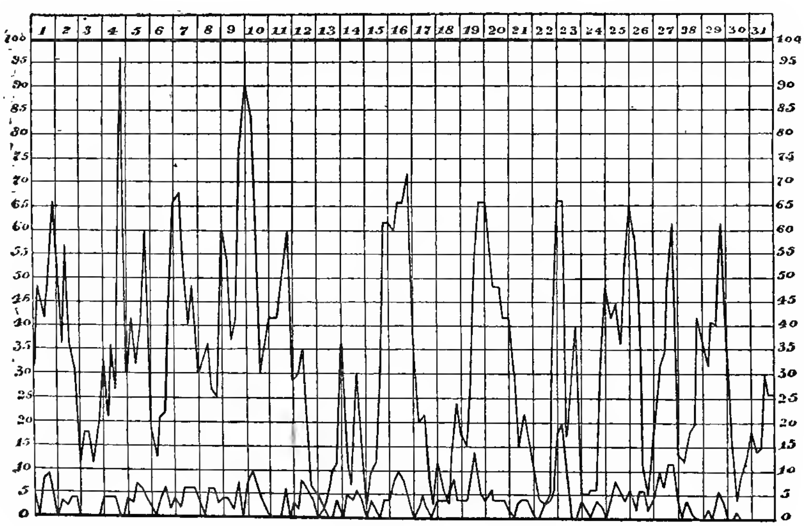


DIAGRAM X.
Velocity of Wind at Summit and at Base of Mt. Washington; May, 1872.

RAIN TABLES.

COMPILED FROM THE SMITHSONIAN RAIN TABLES AND OTHER OBSERVATIONS, BY J. H. HUNTINGTON.

Names of Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter.	Year.	Extent of Series. Yr.	Extent of Series. Mo.	Date. Beg'n'g.	Date. End.		
Cornish, Me.,	3.70	3.86	4.41	4.07	3.36	3.60	4.21	4.67	2.99	4.46	4.91	3.61	11.84	12.48	12.36	11.17	47.85	11	2	Apr., '56	Dec., '66	G. W. Guptill and S. West.	P.O. & S.I., Vol.I, & S.O.
Fryeburg, Me.,	2.45	3.18	2.12	3.52	3.86	3.29	2.17	5.59	3.69	4.84	5.99	4.41	9.50	11.05	14.52	10.04	45.11	5	.....	Feb., '49	May, '56	G. B. Barrows.	S.C. & P.O. & S.I., Vol.I, '61.
Ft. Constitution,	2.42	2.64	2.16	3.44	3.44	3.01	2.40	3.80	2.43	3.29	3.23	3.32	9.04	9.21	8.98	8.38	35.58	12	5	Apr., '36	Sept., '53	Ass't Surgeon.	Army Med. Reg., 1855.
Portsmouth,	3.39	2.47	2.04	1.01	3.02	2.72	2.20	3.41	1.99	3.76	2.29	1.58	6.07	8.33	8.04	7.44	29.88	4	.....	June, '43	to 1848	Surgeon Delany.	S'm Coll'n.
Londonderry,	3.69	3.93	2.47	4.50	5.53	2.33	2.07	4.89	2.07	5.26	5.01	3.86	12.50	9.29	12.34	11.48	45.61	6	11	Mar., '49	Feb., '67	R. C. Mack.	S.C. & P.O. & S.I., Vol.I.
Manchester,	2.74	3.94	2.07	4.78	4.83	1.94	2.86	6.33	3.84	3.68	4.06	4.10	11.68	11.13	11.58	10.78	45.17	4	9	Feb., '52	Mar., '61	S. N. Bell. [man.	S.C. & P.O. & S.I., Vol.I, & S.O.
N. Barnstead,	2.43	1.88	2.70	1.91	4.60	1.70	2.37	3.59	2.56	3.78	3.45	2.02	9.21	7.66	9.79	6.33	32.99	3	1	Mar., '56	Nov., '66	R. T. Hanscom and C. H. Pit-	P.O. & S.I., Vol.I, & S.O.
Ashland,	4.02	3.56	3.70	3.38	3.39	2.50	4.32	4.18	3.77	5.54	4.57	3.57	10.47	11.00	13.88	11.15	46.50	4	.....	Jan., '70	Dec., '73	Winnipiseogee Lake Co., J. P. Hutchinson, Agent.	Manuscript.
Bristol,	3.84	3.58	4.38	3.41	3.03	3.02	5.12	3.50	3.55	5.51	3.84	3.30	10.82	11.64	12.90	10.72	46.08	4	.....	Jan., '70	Dec., '73		
Lake Village,	3.41	3.55	3.15	3.69	2.48	2.59	4.66	3.38	4.19	4.33	4.55	2.80	9.32	10.63	13.07	9.76	42.78	4	.....	Jan., '70	Dec., '73		
Meredith,	3.38	3.08	3.08	4.75	3.66	2.52	3.41	3.08	4.41	5.12	4.56	2.86	11.49	9.11	14.10	9.33	44.03	6	.....	Jan., '68	Dec., '73	Seneca A. Ladd.	Manuscript.
Wiers,	3.63	3.67	3.84	3.02	2.45	2.94	4.59	3.58	3.83	4.24	4.06	3.01	9.31	11.11	12.13	10.31	42.86	....	.....	Jan., '68	Dec., '73	Winnipiseogee Lake Co., J. P. Hutchinson, Agent.	Manuscript.
Wolfeborough,	3.53	2.81	4.01	3.32	2.18	2.67	4.85	3.84	2.45	4.20	3.66	2.44	9.57	11.36	10.31	8.78	39.96	....	.....	Jan., '68	Dec., '73		
Concord,	2.92	3.34	2.38	3.49	3.97	2.72	3.68	4.17	3.43	4.26	3.62	3.01	9.84	10.57	11.31	9.27	40.99	8	9	Jan., '49	Dec., '66	Dr. W. Prescott, E. P. Colby, H. E. Sawyer, J. T. Wheeler.	Manuscript. P.O. & S.I., Vol.I., & S.O.
Claremont,	2.96	3.26	4.99	3.32	3.96	2.93	3.94	4.92	3.51	4.15	2.38	3.37	12.27	11.79	10.04	9.59	43.69	6	5	Sept., '57	Dec., '66	A. Chase and T. N. Freeman.	
West Enfield,	3.72	1.46	2.50	5.37	3.25	3.69	9.25	4.28	3.69	5.85	2.96	1.75	11.12	17.22	12.50	6.93	47.77	2	1	July, '56	Dec., '58	N. Purmort.	P.O. & S.I., Vol.I.
Hanover,	2.86	2.70	2.98	3.13	3.46	3.89	3.41	3.79	3.17	4.01	3.40	3.52	9.57	11.09	10.58	9.08	40.32	19	.....	Jan., '35	Dec., '54	Prof. Ira and A. A. Young.	S.C., P.O., S.I., Vol.I.
Mt. Washington,	1.67	.29	.83	.07	4.62	18.46	3.59	6.33	9.56	6.10	3.52	.85	5.52	28.37	19.08	2.81	55.79	1	.....	Oct., '71	Sept., '72	U. S. Signal Service.	
Stratford,	2.77	2.52	3.47	2.48	3.31	3.24	4.42	3.84	3.98	3.64	3.21	3.08	9.26	11.50	10.83	8.37	39.96	9	3	Mar., '56	Dec., '66	B. Brown.	P.O. & S.I., Vol.I., & S.O.
Woodstock, Vt.,	2.50	1.45	1.67	2.78	4.95	3.06	4.94	4.33	3.44	5.25	2.96	3.25	9.40	12.33	11.65	7.20	40.58	2	.....	Jan., '57	Dec., '58	C. Marsh.	P.O. & S.I., Vol.I.
Lunenburg, Vt.,	3.22	2.09	3.17	2.51	4.27	2.02	3.45	3.37	4.12	3.84	3.37	4.15	9.95	8.84	11.33	9.46	39.58	4	10	Sept., '59	Dec., '66	H. A. Cutting.	P.O. & S.I., Vol.I., & S.O.

TABLES OF MONTHLY SNOW AND RAIN FALL, MONTHLY MEAN, MAXIMUM, AND MINIMUM TEMPERATURES,

Compiled from the Smithsonian and other Observations, by J. H. HUNTINGTON.

1868.

Station		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
CLAREMONT.	Snow,—inches,	26.50	5.	8.12	16.1								
	Rain, or melted snow,	2.65	.50	2.30	2.94	4.	3.60	1.85	5.93	5.50		6.88	
	Date,	2, 3	20	31	1	27	20	13	19	11		1	
	Thermom., maximum,	39	45	60	67	80	90	96	86	77		52	
	Date,	13	24	1	10	4, 8	10	27	13	18, 19		17	
	Thermom., minimum,	—9	—13	—10	16	35	45	59	46	34		20	
	Mean,	17.43	14.23	31.43	39.40	55.08	65.40	74.10	66.70	57.30		33.2	
STRATFORD.	Snow,—inches,	22.	20.	13.	17.5								
	Rain, or melted snow,	2.20	2.	2.20	2.90	3.84	2.30	3.05	2.42	6.17	1.26	6.88	2.45
	Date,	23	20	16	16, 29	27, 28	18	13	2	12	5	1	21
	Thermom., maximum,	32	36	59	62	84	95	100	86	84	64	50	33
	Date,	13	8	1	10, 13	1, 2	2	23	17	18	24	17	27
	Thermom., minimum,	—15	—24	—13	9	32	42	54	46	30	10	5	—20
	Mean,	12.58	9.05	27.10	33.53	51.91	62.03	72.12	65.40	53.19	38.6	27.6	13.9
WOODSTOCK, Vt.	Snow,—inches,	.35	4.	.17	22.	1.					4.	16.	25.
	Rain, or melted snow,	3.50	.04										
	Date,	3	21	27	16	29	18	13	3, 19, 26	13	8	1	21
	Thermom., maximum,	49	45	53	70	77	87.5	95	84	80	73	56	38.5
	Date,	13	8	1	10	4	3	27	17	18	24	24	25
	Thermom., minimum,	—20	—33	—28	—2.5	28	35	46	39	27	10.5	12	—27
	Mean,	13.58	10.29	17.74	36.79	52.41	63.11	71.81	64.17	53.76	39.49	29.86	14.47
LUNENBURG, Vt.	Snow,—inches,	18.75	14.50	13.	5.50								
	Rain, or melted snow,	1.87	1.45	1.50	1.30	4.50	4.40	4.62	1.81	8.08	1.30	7.15	2.45
	Date,	2	20	31	16	28	18	13, 15	3	12	7	1	21
	Thermom., maximum,	33	37	57	68	77	87	75	85	80	65	54	32
	Date,	13	24	1	10	9	3	23	17, 28	18	30	17, 30	27
	Thermom., minimum,	—16	—27	—12	4	32	36	53	49	25	15	14	—30
	Mean,	12.2	8.78	27.93	34.	52.48	62.15	71.58	66.73	54.58	41.6	29.60	13.82

1869.

Station		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
DUNBARTON.	Snow,—inches,	17.50	34.5	19.3	1.2						3.2	4.	16.
	Rain, or melted snow,	2.71	3.5	3.4	1.5	3.4	3.1	1.6		3.87	1.	2.16	2.79
	Date,	8	13	28	28	12	4	11		5	1	5	17
	Thermom., maximum,	49	50	56	74	87	88	88		87	67	63	44
	Date,	22	2	6	3, 4	1, 2	7	1		28	28	16	8
	Thermom., minimum,	—1	6	—1	26	32	42	49		35	26	18	6
	Mean,	26.20	27.08	26.38	41.98	52.73	63.05	68.85		61.48	47.18	35.10	27.29
STRATFORD.	Snow,—inches,	10.5	54.	19.5	1.30	4.5					7.	6.	24.
	Rain, or melted snow,	1.05	5.4	3.60	2.63	3.97	4.39	2.36	3.17	3.39	7.76	2.23	2.18
	Date,	4	13	28	20	31	4	26, 28	10	14	2	4	27
	Thermom., maximum,	37	38	48	67	83	86	86	84	83	75	60	44
	Date,	7, 8	8	1	4	1	9	1	31	28	28	26	8
	Thermom., minimum,	—15	—12	—22	18	32	41	48	46	33	20	8	—15
	Mean,	15.48	18.74	19.21	37.20	51.02	58.86	64.99	59.97	59.02	41.19	28.38	21.21
WOODSTOCK, Vt.	Snow,—inches,	22.	40.	26.	2.	5.					1.50	6.	14.30
	Rain, or melted snow,						2.85	1.76	2.24	3.44	12.90	2.29	2.94
	Date,	8	13	27	27	12	4	25	20	7, 8, 20	14	4	1
	Thermom., maximum,	50	50.5	53	66	85	84	86	88	82	73	59	53
	Date,	23	8	1	11	1	7	6	8	28	28	26	8
	Thermom., minimum,	—25.5	—21	—28	17	23	32	40	35	31	18	7	—18
	Mean,	19.08	19.37	17.74	39.71	52.51	59.84	65.22	61.59	59.12	41.86	30.	22.44
LUNENBURG, Vt.	Snow,—inches,	18.	36.	19.5	3.	1.					3.5		7.75
	Rain, or melted snow,	1.95	3.67	2.5	1.75	2.75	5.	2.75	2.50	2.60	7.72		2.25
	Date,	13, 19	13	28	20	31	4	11	25	17	1		1
	Thermom., maximum,	35	39	47	61	78	84	84	78	82	72		40
	Date,	8	8	2	5	1, 4	6	1	31	28	28		8
	Thermom., minimum,	—20	—12	—23	20	34	46	52	48	36	21		—12
	Mean,	14.73	19.80	19.43	38.25	53.88	60.93	67.58	63.43	61.60	42.90		21.93

TABLES OF MONTHLY SNOW AND RAIN FALL, MONTHLY MEAN, MAXIMUM, AND MINIMUM TEMPERATURES.

Compiled from the Smithsonian and other Observations, by J. H. HUNTINGTON.

1870.

Station		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
WHITEFIELD.	Snow,—inches,	22.50	28.25	17.61								14.85	11.40
	Rain, or melted snow,	2.25	5.15	4.41	1.86	1.74	4.56	2.47	3.63	.44	2.69	4.85	1.14
	Date,	17	18	31	28	29	24	24	19	2	16	2	1
	Thermometer, maximum,	52	46	55	78	84	92	92	89	82	71.5	58.5	45
	Date,	14, 16	4	12	1	7	21	1	27	12	27	22	30
	Thermometer, minimum,	—12	—12	—17.5	20	31	51.2	50	37.5	36.75	16	12.5	—18.7
	Mean,	22.50	16.35	24.18	43.65	53.23	68.28	69.98	64.35	56.75	45.73	33.38	22.20
STRATFORD.	Snow,—inches,	35.30	42.50	11.							2.5	11.5	17.
	Rain, or melted snow,	4.15	5.19	3.54	2.22	2.48	1.63	2.47	3.86	1.45	4.47	4.33	1.70
	Date,	17	18	31	27	30	24	24	7	2	2, 16	2	2
	Thermometer, maximum,	42	44	54	72	86	92	98	89	86	70	58	44
	Date,	14	4	12	1	5, 12	21	1	27	12	27	16	30
	Thermometer, minimum,	—12	—12	—18	25	33	48	52	40	35	20	12	—12
	Mean,	21.30	15.43	23.60	42.83	52.14	68.25	70.05	63.88	56.98	44.80	32.18	20.83
WOODSTOCK, Vt.	Snow,—inches,	25.39	36.50	24.50	3.50						4.	2.	26.75
	Rain, or melted snow,	6.20	5.12	2.60	3.27	1.81	5.35	1.82	1.03	4.93	3.80	1.87	2.51
	Date,	23	12, 18	30	28	16	25	24	9	1, 2	16	9	23
	Thermometer, maximum,	52	45	57	78	83.5	91.5	90	91.5	85	70	61	51.5
	Date,	14	5	4	1	6	23	2	27	13	27	16	21
	Thermometer, minimum,	—5	—14	—8	18	29.5	49	43	34	31.5	17	15	27
	Mean,	23.60	16.07	23.66	42.04	54.05	68.04	70.10	65.61	57.01	45.71	34.17	16.49
LUNENBURG, Vt.	Snow,—inches,	23.05	40.	17.25							.50	9.	8.
	Rain, or melted snow,	4.55	4.10	4.52	2.50	4.00	3.5		6.42	3.	3.95	5.25	1.30
	Date,	17	18	31	27	30, 31	29		9	4	12	9	2
	Thermometer, maximum,	42	44	52	68	82	94		90	80	79	56	40
	Date,	14	2	12	4	7	22		26	12	27	22	25
	Thermometer, minimum,	—12	—13	—15	25	35	50		48	38	17	18	—18
	Mean,	21.88	16.23	23.73	42.70	53.43	68.68		67.25	59.75	46.20	33.55	21.55
TAMWORTH.	Snow,—inches,	27.97	40.70	24.40	2.10						4.81	6.41	13.50
	Rain, or melted snow,	8.58	7.50	2.48	5.99	1.03	2.63	1.62	2.45	1.15	5.58	4.05	1.95
	Date,	23	15	30	28	30	25	24	9	1	16, 25	5	1
	Thermometer, maximum,	50	52	50	79	83	95	97	96	85	71	56	49
	Date,	14	5	4	1	7	29	1	27	27, 29	27	17	20, 24
	Thermometer, minimum,	—9	—20	—4	25	37	53	93	48	34	10	15	—13
	Mean,	23.98	18.05	26.80	43.19	55.50	69.09	71.32	68.20	57.99	46.77	35.27	25.65

TEMPERATURE

PREPARED FOR THE GEOLOGICAL SURVEY OF

Name of Station.	Height.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter.
		°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Charlestown,	....	.....	.....	.....	41.97	.....	.....	69.96	68.11	.....	45.67	.....	26.51	.....	.....	.....	.....
Claremont,	575	18.35	22.47	30.79	43.51	54.96	65.27	69.21	66.56	58.48	46.53	37.11	23.68	43.09	67.01	47.37	21.50
Concord,	292	20.84	22.73	31.49	43.21	56.17	65.86	69.91	66.80	59.15	48.82	37.96	24.87	43.62	67.52	48.64	22.81
Contoocookville,	381	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	39.83	28.88	.....	.....	.....	.....
Dover,	150	24.	23.60	31.80	42.70	53.70	63.90	70.40	64.70	58.80	46.40	35.50	25.20	42.73	66.33	46.90	24.27
Dublin,	1869	18.52	21.58	27.70	36.99	49.14	63.18	67.15	64.18	57.37	45.44	33.67	21.14	37.94	64.84	45.49	20.41
Dunbarton,	750	27.74	24.78	30.08	42.60	54.54	66.44	72.84	70.25	61.20	48.89	36.65	26.38	42.41	69.84	48.91	26.30
Epping,	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Exeter,	58	19.89	21.20	31.41	40.85	54.47	63.81	69.89	67.82	59.	49.22	38.06	25.33	42.34	67.17	48.76	22.14
Farmington,	300	22.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Farmouth, *b*	490	23.98	22.15	26.41	43.19	55.50	69.09	71.32	68.20	57.99	45.38	33.13	24.	41.70	69.54	45.50	23.38
Ft. Constitution,	40	24.89	26.26	34.37	43.26	53.50	62.34	67.06	65.06	59.12	49.64	38.89	28.74	43.71	64.82	49.19	26.63
Francestown,	....	18.58	24.29	30.08	42.	53.50	64.09	69.32	68.15	59.45	47.09	38.19	29.46	41.89	67.19	48.24	24.11
Great Falls, *c*	250	21.32	20.25	31.96	41.73	56.83	64.78	75.50	68.90	60.98	51.01	38.16	22.13	43.15	69.73	50.05	21.23
Hanover (D.C.),	604	16.24	15.47	26.15	37.66	52.53	61.69	65.68	63.34	55.55	44.30	32.31	17.08	38.78	63.57	44.05	16.26
Hanover, *d*	604	17.62	18.89	29.10	40.10	53.40	62.70	67.15	65.60	56.33	44.18	33.76	20.99	40.87	65.15	44.76	19.17
Keene,	....	.....	.....	.....	41.20	54.60	.....	68.79	70.40	....	44.80	31.20	25.50	.....	.....	.....	.....
Littleton, *e*	....	17.57	18.40	24.44	38.62	52.84	58.91	66.60	65.81	55.58	46.60	33.90	15.09	38.63	63.77	45.36	17.02
Londonderry,	300	22.64	24.38	31.89	43.48	56.21	66.36	71.69	68.41	61.09	50.61	38.87	26.91	43.86	68.82	50.19	24.37
London Ridge,	475	23.70	30.77	38.45	49.18	62.23	67.20	74.08	72.85	70.25	.....	42.28	33.03	46.65	71.38	.....	29.17
Manchester,	300	23.84	26.38	34.06	45.01	64.34	67.54	72.94	69.67	62.11	51.09	40.22	27.48	47.80	70.02	51.14	25.90
Mason,	....	29.10	31.70	30.15	43.60	.....	66.10	68.80	67.90	.....	.....	.....	26.20	.....	67.60	.....	29.
Mt. Washington,	6293	6.4	6.9	9.7	22.6	33.3	44.5	47.9	50.7	39.3	29.8	16.5	5.4	21.8	47.7	28.5	6.2
N. Barnstead, *g*	....	21.65	24.74	31.03	43.27	54.49	64.04	69.	68.12	60.86	48.29	38.77	25.44	42.93	67.05	49.31	23.94
Portsmouth,	12	25.45	27.75	30.85	47.15	57.10	65.80	69.65	68.15	60.35	48.80	34.80	26.20	45.03	67.87	47.98	26.47
Portsmouth,	12	21.62	27.48	36.	43.07	53.	63.96	69.37	67.64	59.64	47.63	36.36	26.35	44.02	66.99	47.84	25.15
Salisbury,	....	18.83	20.32	31.42	42.15	.....	.....	.....	.....	61.55	47.43	36.27	27.30	.....	.....	48.42	22.15
Shelburne,	728	16.32	19.26	27.44	39.80	52.07	62.91	69.36	64.18	55.46	43.78	33.35	20.21	39.77	65.48	44.20	18.60
Stratford,	1000	13.27	17.17	24.92	37.37	50.84	61.36	65.21	62.27	54.46	42.21	31.37	16.07	37.71	62.95	42.68	16.07
Wakefield,	....	28.	28.80	39.25	49.80	61.20	73.40	79.40	77.20	67.60	52.80	44.20	31.80	50.08	76.67	54.86	29.53
West Enfield,	....	20.10	20.11	27.25	39.07	51.77	63.86	68.73	65.48	58.26	45.58	31.86	19.53	39.36	66.02	45.23	19.92
Whitefield,	1332	22.50	16.35	24.18	43.65	53.23	64.48	67.61	62.42	57.68	43.43	31.36	21.73	40.35	64.84	44.16	20.19

TABLES,

NEW HAMPSHIRE BY THE SMITHSONIAN INSTITUTION.

Year.	Series.		Extent.		Observing hours.	Observer.	References.
°	Begins.	Ends.	Yr.	Mo.			
.....	1843	1844	..	5	....	....	Manuscript.
44.74	Sept.,'57	Nov.,'68	9	7	7m, 2a, 9a, *bis*	F. A. Freeman, A. Chase, S. O. Mead.	P. O., S. I., Vol. I, S. O.
45.66	Jan., '28	May, '70	22	2	7m, 2a, 9a	J. Farmer, Dr. Prescott, H. E. Sawyer, J. T. Wheeler, J. C. Knox.	P. O., S. I., Vol. I, S. O. Am. Alm., '37 and foll., S. Coll.
.....	1870	1870	..	2	7m, 2a, 9a, *bis*	E. D. Couch.	S. O.
45.08	Jan., '33	July, '43	10	7	⊙r, 1a, 10a	A. A. Tufts.	Am. Alm., 1836, 1837, and foll.
42.17	Jan., '49	Aug., '53	4	8	⊙r, 9m, 3a, 9a	Leonard.	S. Coll.
46.87	Mar., '68	Dec., '70	2	10	7m, 2a, 9a, *bis*	A. Colby.	S. O.
44.76	1833	1834	2	..	....	Plummer.	Am. Alm.
45.10	1849	May, '63	6	11	7m, 2a, 9a, *bis*	Rev. L. W. Leonard, E. Nason.	S. O., S. Coll.
.....	1861	1861	..	1	....	L. Bell.	S. O.
45.03	Feb., '67	Dec., '70	1	4	7m, 2a, 9a, *bis*	A. Brewster.	S. O.
46.09	Jan., '22	Sept., '53	25	2	7m, 2a, 9a	Ass't Surgeon.	A. M. R., 1855.
45.36	Mar., '53	May, '58	2	3	7m, 2a, 9a	A. H. Bixby, Dr. M. N. Root, Sawyer.	P. O., S. I., Vol. I, S. Coll.
46.13	1853	Jan., '57	1	2	7m, 2a, 9a	G. B. & H. E. Sawyer, Titcomb.	P. O., S. I., Vol. I, S. Coll.
40.67	Nov., '34	Dec., '54	4	..	⊙r, 1½a, 9½a	Prof. I. Young, A. A. Young.	P. O., S. I, Vol. I, Am. Alm., 1837 and foll.
42.49	1835	1854	20	..	⊙r, 1½a, 9½a	Young.	Manuscript.
.....	1843	1843	..	7	⊙r, 9m, 3a, 9a	Whalock.	Manuscript.
41.20	Mar., '63	July, '64	1	5	7m, 2a, 9a, *bis*	R. C. Whiting, R. Smith.	S. O.
46.88	Mar., '49	Feb., '57	5	10	7m, 2a, 9a	R. C. Mack.	P. O., S. I., Vol. I, manuscript.
.....	Jan., '62	Feb., '63	1	..	7m, 2a, 9a, *bis*	Dr. I. S. French.	S. O.
48.72	Jan., '45	Mar., '60	14	1	⊙r, 2a, ⊙s	S. N. Bell.	P. O., S. I., Vol. I, S. Coll., S. O.
.....	Jan., '06	June, '07	..	10	*f*	....	Med. & Aqr. Reg., Boston, Vol. I, 1806, 1807.
2.8	1853	1859	..	3	7m, 2a, 9a	J. S. Hall, Noyes.	P. O., S. I., Vol. I, printed reg.
45.81	Feb., '60	Dec., '68	8	8	7m, 2a 9a, *bis*	C. H. Pitman.	S. O.
46.84	Feb., '06	Sept., '07	1	5	*f*	C. Pierce.	Med. & Aqr. Reg., Boston, Vol. I, 1806, 1807.
45.42	Jan., '39	July, '68	9	11	⊙r, 9m, 3a, 9a	J. Hatch, Surg. Delaney, Chase.	MS. in S. Coll., S. O., S. Coll.
.....	Nov., '61	Oct., '70	..	8	7m, 2a, 9a, *bis*	E. D. Couch.	S. O.
42.01	Dec., '56	May, '69	6	9	*h*	F. Odell.	P. O., S. I., Vol. I, S. O.
39.85	Aug., '55	Dec., '70	13	4	7m, 2a, 9a, *bis*	W. B. G., B. G. & B. Brown, A. Wiggin.	P. O., S. I., Vol. I, S. O.
52.78	1846	1850	5	..	*N*	Dow.	Manuscript.
42.38	Sept., '56	Dec., '58	2	3	7m, 2a, 9a	N. Purmort.	P. O., S. I., Vol. I.
42.39	June, '69	Dec., '70	1	7	7m, 2a, 9a, *bis*	L. D. Kidder.	S. O.

NOTES AND ABBREVIATIONS USED IN TABLES.

b. Also called Tamworth.

c. This series is composed of observations at Great Falls, by H. E. Sawyer, and at Salmon Falls, about two miles south-east of Great Falls, by G. B. Sawyer.

d. Observations from January, 1835, to December, 1837, probably included in preceding series.

e. This series is composed of observations at Littleton, by R. C. Whiting, and at North Littleton, about one mile north of Littleton, by R. Smith.

f. The observing hours were ⊙r., 2a. The observations were corrected for daily variation by means of the general table.

g. Also called Barnstead.

h. Observations corrected for daily variation by means of the general table.

9 *bis*. indicates that the 9 o'clock observation is used twice.

The abbreviations, used in the last column headed "References," are principally the following:

Am. Alm. denotes the American Almanac, Boston.

P. O., S. I., Vol. I denotes the results of the meteorological observations made under the direction of the Patent Office and the Smithsonian Institution, Washington, 1861.

S. O. denotes the manuscripts by the observers of the Smithsonian Institution.

S. Coll. denotes manuscripts collected at different times by the Institution.

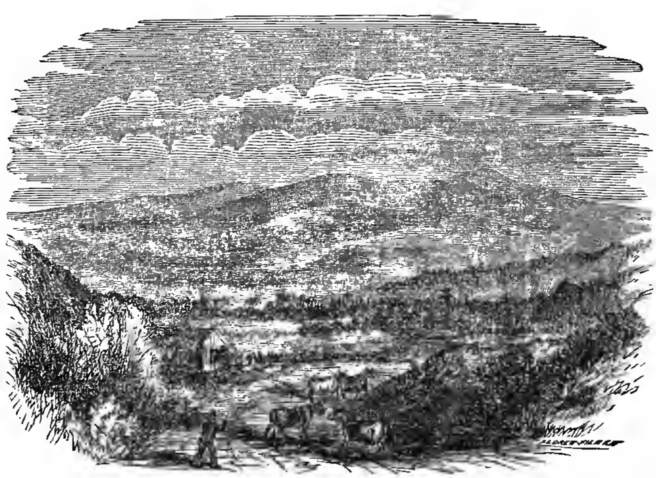


Fig. 19.—Mt. Moriah in Gorham.

CHAPTER VI.

THE USE OF THE MAGNETIC NEEDLE IN SURVEYING.

By E. T. QUIMBY, A. M.,
PROFESSOR OF MATHEMATICS AND CIVIL ENGINEERING, DARTMOUTH COLLEGE.

THE object of this paper is to explain the facts of terrestrial magnetism, so far as they relate to the use of the magnetic needle by the surveyor, with particular reference to the state of New Hampshire. It will not therefore be necessary to describe the construction and use of the instruments by means of which these facts have been observed, nor to discuss the formulæ for the reduction of the observations. Those who wish to make a thorough examination of this subject are referred to the works of Airy, Walker, and others, and to the reports of the United States Coast Survey, under whose auspices extensive magnetic observations have been and are still being made in various parts of our country.

It may seem of little importance to reproduce what has been so long known, when nothing specially new can be added; but an examination of the records of surveys made within the last fifty years will show that there is need either of more general knowledge on this subject, or of a better use of what is known. It is quite unusual to find in any of these records the slightest reference to magnetic declination; and there is reason to believe that surveyors sometimes rely too implicitly upon the needle in retracing old lines by their former magnetic bearings. It will appear by the behavior of the needle that, while it is a valuable aid, it can

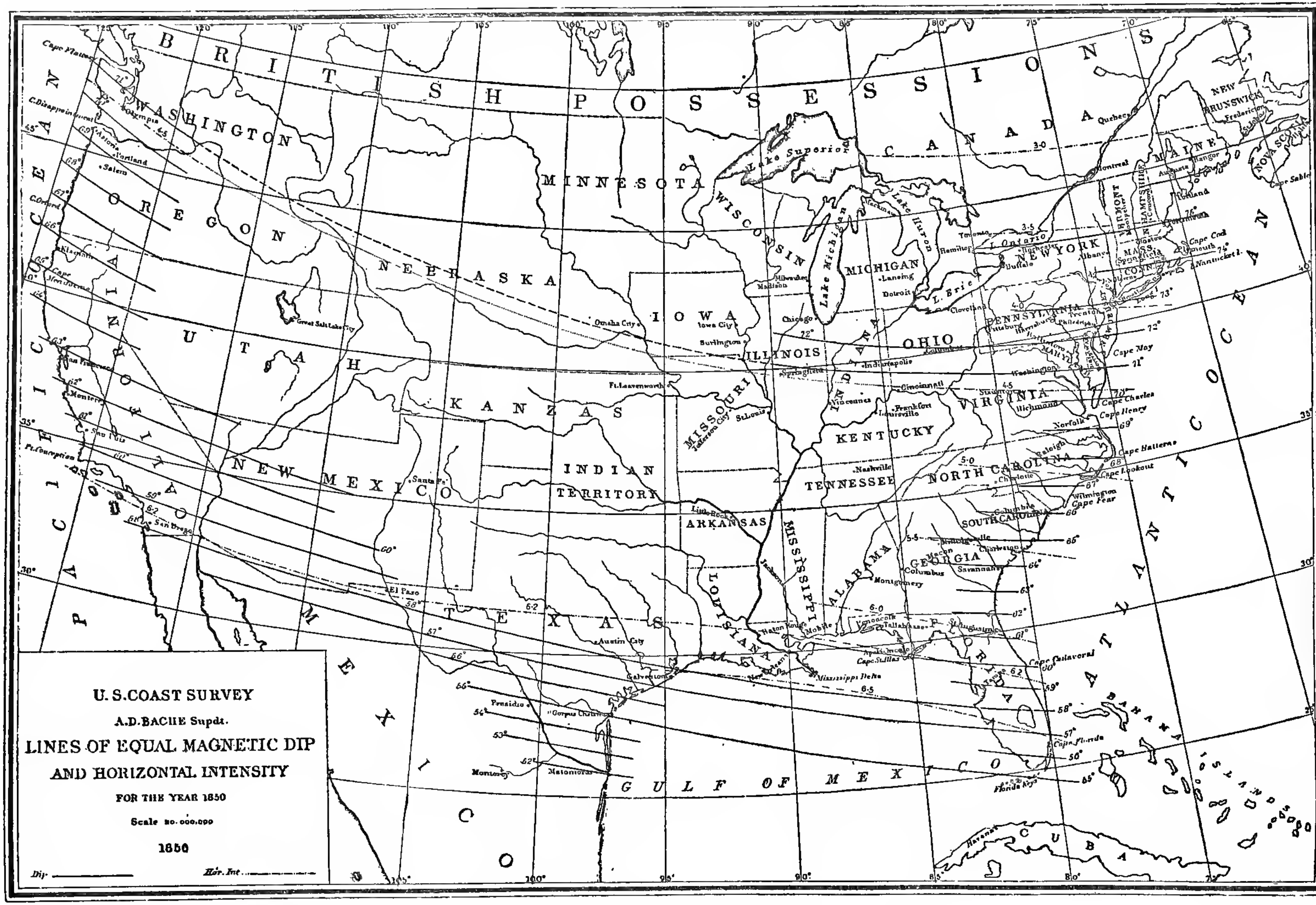
never be depended on for such purposes, and should, in all cases, be used with caution, and only when extreme accuracy is not required.

It is well known that a bar (not magnetic) suspended from its centre of gravity will remain in any position in which it may be placed, unless disturbed by some extraneous force; but if the bar be made of steel, and magnetized, it will assume a definite direction, and, when disturbed, will invariably return to the same direction when the disturbing force ceases. This directive property of the magnet was known to the Chinese, and probably in Europe, as early as the twelfth century; and the magnetic needle has from that time been used to guide ships upon the seas, and for exploring and other purposes upon the land. This needle consists of a slender magnetized steel bar, balanced upon a pivot at a point considerably above its centre of gravity, that it may retain its horizontal position; and, when left free to turn upon its pivot, it comes to rest, by the action of the earth's magnetism, *approximately* in the plane of a meridian: hence one end is called the north pole, and the other the south pole of the magnet, and a vertical plane through the needle is termed the *magnetic meridian.* It is not certain at what time the deviation of the *magnetic* from the *true* meridian (called the *declination* of the needle) first became known, but it is evident that it could not have been long after the directive property itself was discovered. There is, however, no reliable record of any experiments to determine the amount of this declination prior to the discovery of America, although it is probable such experiments were made. It seems likely, also, that this declination was previously supposed to be constant, or nearly so, for all times and places,—as Columbus and his sailors were not a little surprised, and some of them alarmed, on the 13th of September, 1492, to find that the needle, which at the commencement of their voyage pointed east of north, had changed to west of north. Since that time the interest in terrestrial magnetism, among scientific men, has been increasing; and observations, at first with instruments rudely constructed, but more recently with those of extreme delicacy, have revealed facts, a knowledge of which is important to every one using the magnetic needle.

To make the statement of these facts plain, let us recur to our magnetized bar which we supposed to be suspended from its centre of gravity. This magnet, if left free to turn about the point of suspension in all

directions, will take a position in the magnetic meridian which (if the observation be taken at Hanover) will deviate from the true meridian about 11°, the north end of the magnet turning to the west of north. Moreover, also, it will incline to the horizon, the north pole dipping downward at an angle of about 75° 30′. This is called the *inclination* or *dip* of the needle. It becomes necessary, therefore, in studying the phenomena of terrestrial magnetism, to make use of two instruments,—one for observations upon the *declination*, and the other upon the *dip* of the needle. In the former, the needle hangs horizontally in a stirrup suspended by a fibre of untwisted silk, which leaves it free to turn in a horizontal plane with the least possible resistance; while the latter, called the dipping needle, is balanced upon a horizontal axis, and is free to turn only in a vertical plane, and when in use must have its axis perpendicular to the plane of the magnetic meridian. Besides the *declination* and *dip*, we may also consider the *intensity* of terrestrial magnetism, by which is meant the amount of that force which restores the needle, when disturbed, to its normal direction. This element is of so little practical importance in the ordinary use of the needle, that it may be passed briefly.

Intensity of Terrestrial Magnetism. If a magnetic needle,—suspended, as mentioned above, by a fibre of silk,—be drawn out of the magnetic meridian by bringing near it another magnet, and then allowed to return by removing the second magnet to a distance, it will oscillate for a time before the resistance of the air and of the suspending fibre will bring it to rest. If the weight and dimensions of the needle are accurately known, and the number of oscillations it makes in a given time be observed, it is easy to compute the intensity of the force which actuates it, the more rapid oscillation indicating the greater force. This, however, will not represent the total force of the earth's magnetism, but only that part of it which tends to bring the needle into the plane of the magnetic meridian, and which is called the *horizontal intensity*, or the *horizontal component* of the magnetic force. The *vertical component* tends to draw the north end of the needle downward (in the Northern hemisphere), causing the *dip*. The actual direction of the force of terrestrial magnetism at any place is the same as that of a magnetic needle suspended from its centre of gravity, and free to move in all directions, or of the dipping-needle when

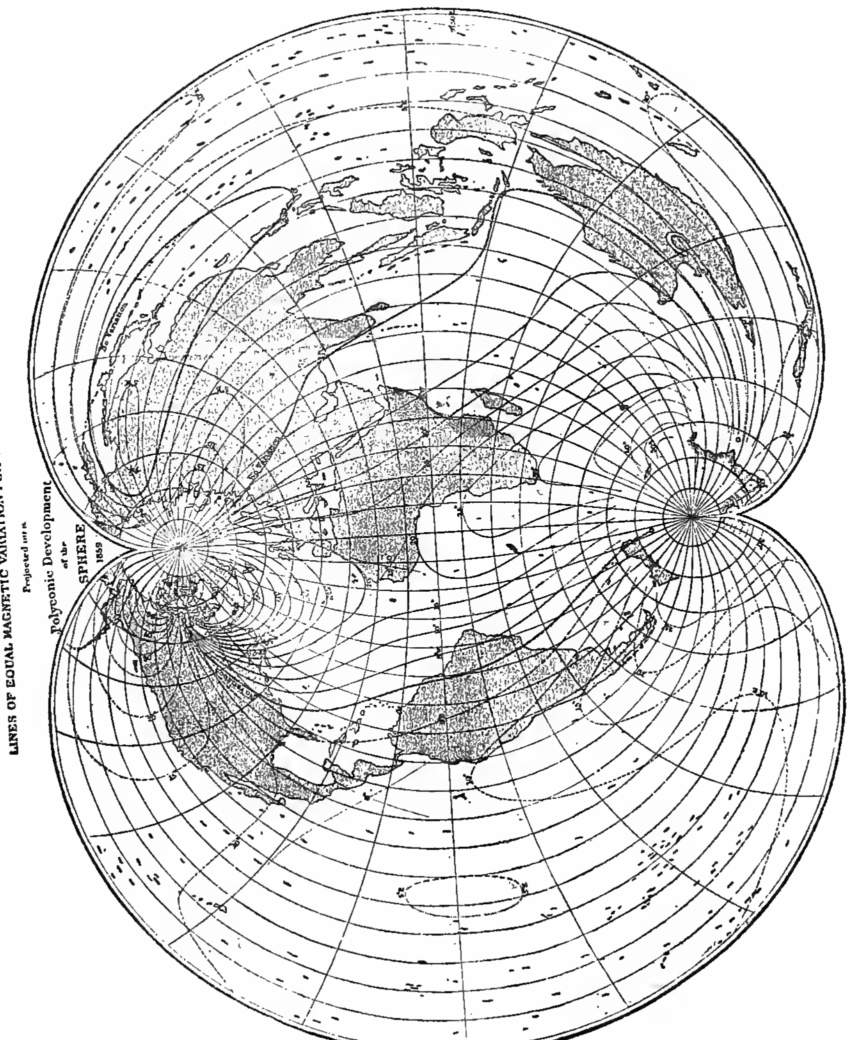

U. S. COAST SURVEY
A.D. BACHE Supdt.
LINES OF EQUAL MAGNETIC DIP
AND HORIZONTAL INTENSITY
FOR THE YEAR 1850
1850
BRITISH POSSESSIONS
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
CUBA

placed in the plane of the magnetic meridian. As we go towards the south, the vertical component of this force diminishes, and the horizontal component increases, as will be seen by the United States Coast Survey chart (p. 6) showing lines of equal horizontal intensity, and, also, of equal dip. Neither does the magnetic intensity remain the same for the same place. Observations made at Washington, D. C., by the United States Coast Survey, show that the total force at that place has heretofore been slightly increasing, while at the present time it is nearly stationary, or, perhaps, beginning to decrease. Like the other magnetic elements, the intensity has its secular period of change, but the data are not at present sufficient to determine that period; and even if it were known, it would be of no practical importance to the surveyor.

Magnetic Dip. When the dipping-needle is placed in the plane of the magnetic meridian,—that is, with its axis at right angles to this plane,—the north end is drawn downwards, making, at Hanover, an angle with the horizon of about 75° 30′. If, now, we carry this needle to the south, we find the dip diminishing, until, near the equator, we reach a place where it is zero. We may then trace a line, approximately east and west, upon which there is no dip. North of this line the north end of the needle will dip, and south of it, the south end. On each side of the line of no dip, we may trace lines of equal dip called *isoclinic lines*. These lines are shown, so far as they have been determined for the United States, on the chart previously referred to (p. 6). Going northward, the dip increases, till, at a magnetic pole, the needle takes a vertical position.

The magnetic dip, like the intensity, is slowly changing, as continued observations upon the dipping-needle show. Previous to 1854, it was increasing in the United States, and since that date it has diminished about 30′.

The use of the magnetic needle in surveying does not require special attention to the dip. It is only necessary to place upon one end of the needle a suitable counterpoise to keep it in a horizontal position, since, when balanced before being magnetized, it will always require such a counterpoise after it is magnetized, unless used upon the line of no dip; and, when balanced for one latitude, it will need readjusting if taken to a different latitude. When the needle is once properly balanced for any place, the surveyor need give no further attention to the dip.


LINES OF EQUAL MAGNETIC VARIATION FOR THE YEAR 1858
Projected on a
Polyconic Development
of the
SPHERE
1859
No Variation

Magnetic Declination. As an instrument for the determination of the true bearings of lines, it is evident that the magnetic needle can be of little value except as we are able to determine accurately its *declination*, or the angle it makes with the true meridian. It is true that, when only a comparison of directions is required, as in the survey of a field to determine its figure and area, it is of no consequence what the declination is, provided it remains the same during the progress of the survey and for all points where the needle is used; but even then, to make the survey useful in retracing the same lines at a future time, the declination should be known and recorded.

By observations upon the needle of a well constructed magnetometer, the following facts relating to the declination will appear, some of which will be indicated even by the ordinary compass needle.

1. The declination is not the same in all places.

2. For a given place it is subject to a secular change of unknown period, but requiring at least several hundred years for its completion.

3. It has a diurnal change, with a maximum and minimum for each day.

4. It has also an annual maximum and minimum, changing with the seasons of the year.

5. It is subject to irregular disturbances, being more or less affected by every meteorological change.

Discussing these in their order, we consider,

1. *The declination in different places.* This is well shown by the chart of the world (p. 8) upon which lines of equal declination, called *isogonic* lines, are drawn. By reference to this chart it will be seen that, on this continent, a line of no declination passes in a north-westerly and south-easterly direction near Cleveland, O., and Raleigh, N. C. At all places east of this line, the declination is westerly,—that is, the north end of the needle points to the west of north; and west of the line the declination is easterly. The map of New Hampshire and Vermont, herewith given, shows the isogonic lines for these states, as delineated by the United States Coast Survey. By observing the situation of a place with reference to these lines, the declination for that place may be approximately determined; but while they may be considered mainly correct for this date (January, 1874), no surveyor should rely upon them for the

declination of a place, when it is possible to determine that declination by a direct observation upon the true meridian.

By the general direction of these lines in New England, it appears that, by moving north-westerly or south-easterly, but little change will be noted in the declination; but in going north or north-east it will increase, and diminish in going south or south-west. The following declinations were observed by Dr. T. C. Hilgard, for the United States Coast Survey, in 1873:

Station.	Date.	Declination.
Gorham,	Sept. 8–11,	12° 42′
Littleton,	Sept. 22–25,	13° 47′
Hanover,	Oct. 2–6,	10° 47′*
Hanover,	Oct. 8–11,	10° 50′*
Burlington, Vt.,	Oct. 12–15,	11° 22′
Rutland, Vt.,	Oct. 17,18,	10° 40′

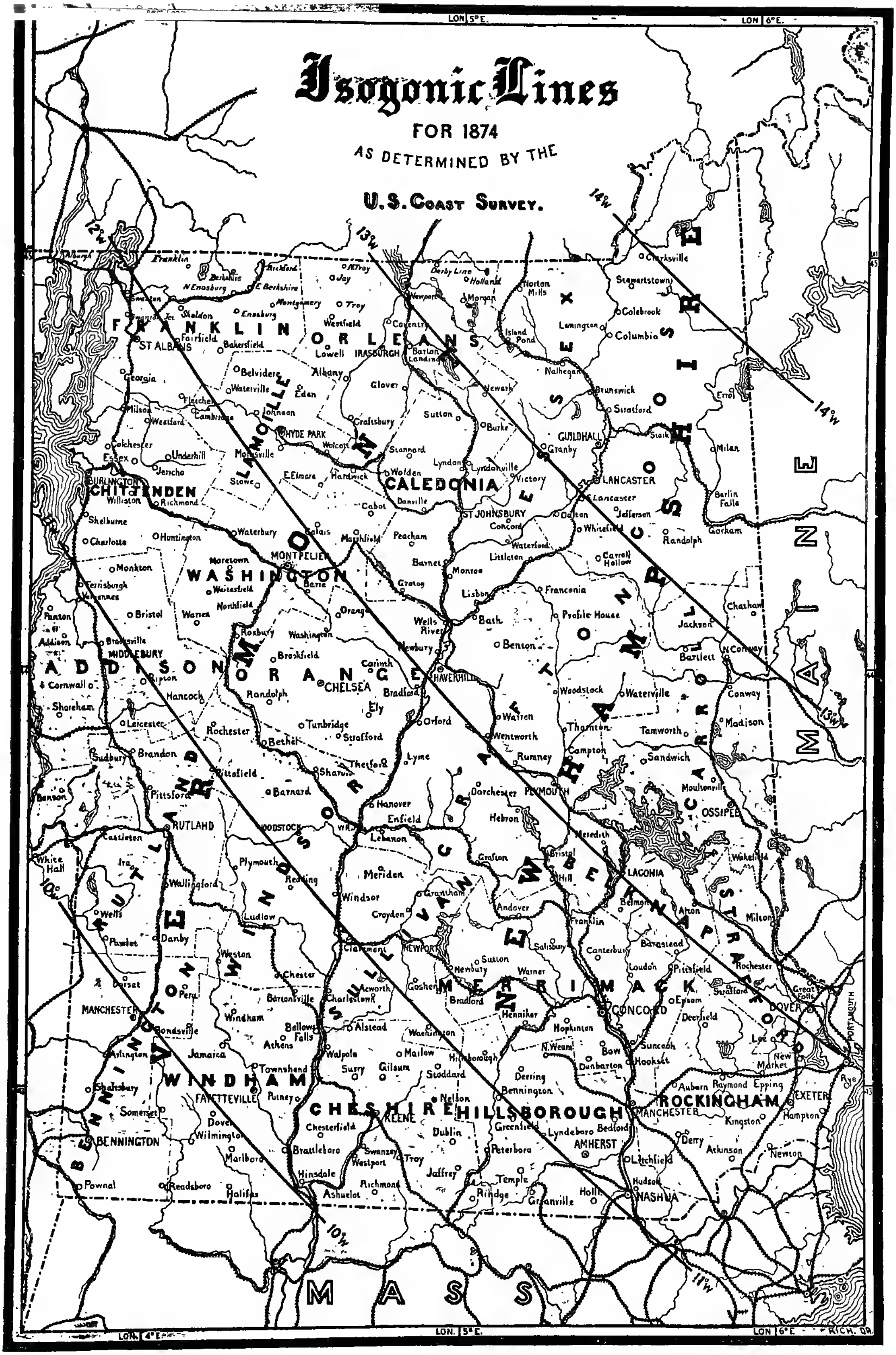
By observations made by Rev. C. A. Downs, of Lebanon, the declination at that place is 11° 30′.

The following declinations are copied from previous observations by the United States Coast Survey:

Station.	Date.	Declination.
Burlington, Vt.,	1855—Aug. 28,	9° 57′.1
Mt. Agamenticus, Me.,	1847—Sept. 23–Oct. 2,	10° 09′.8
Mt. Patuccawa,	1849—Aug. 15–19,	10° 42′.8
Mt. Uncanoonuc,	1848—Oct. 6–8,	9° 04′.1
Isle of Shoals,	1847—Aug. 12–19,	10° 03′.5
Plum Island, Mass.,	1850—Sept. 18–20,	10° 05′.6

2. *Secular Variation of the Declination.* The line of no declination and the other isogonic lines are not fixed in position, but are slowly moving. This motion, in the United States, is at the present time for the most part toward the south-west. In 1801 the line of no declination passed nearly through Annapolis, Md., crossing Lake Erie about forty miles from Buffalo. In 1850 it had gone to the west upon our coast as far as Beaufort, N. C., and, passing west of Pittsburgh, Penn., crossed Lake Erie near its centre. In 1870 it passed very nearly through the cities of Raleigh, N. C., and Cleveland, O. At the present time, the declination is more than 3° upon the line where, in 1801, it was 0°. The influence which causes this change in declination is passing over this continent from north-east to south-west, as will be seen by the following extract from a report on secular changes in declination, &c., by C. A. Schott,

* Probably too small on account of local attraction.



Isogonic Lines
FOR 1874
AS DETERMINED BY THE
U.S. COAST SURVEY.

assistant in charge of the computing division, United States Coast Survey office, Washington, D. C.:

The influence which produced the increase of magnetic *west* declination on our Atlantic coast was first recognized in the north-east, extending itself in time toward the south-west. The minimum west declination occurred at Portland, Me., about 1765; at Cambridge, Mass., about 1783; at New York, about 1795; at Savannah, Ga., about 1817; at New Orleans, La., about 1831; and at the city of Mexico about 1838, appearing at the last three places as a maximum east declination. The same influence will possibly soon reach our Pacific coast, where at present the east declination is still slowly on the increase. Sub-periods or subordinate waves in the secular change have been recognized in the observed declinations at Cambridge, Mass., at Hatboro', Penn. (near Philadelphia), and at other places; and they are also noted in the observed dips at Washington, and Toronto, Canada.

Taking this view of the subject, the phenomenon of the secular change is a complex one; and the numerical formulæ designed for expressing it must, for the present, retain their tentative and hence provisional character; and they should not be used (either way) much beyond the time for which they are supported by observations.

The declination at Hanover in 1840 was $9°\ 20'$ west, and the annual increase at that time $5'.2$. But the whole change since then is only $2°$, being an average of $3'.5$ per annum; and recent observations show that the annual increase during the last decade has been less than $3'$. The present rate of change will not be accurately known until the observations made in September, 1873, shall be repeated. It is probably not more than $2'$ or $2'.5$ per annum, which indicates a probability that the westerly declination will reach a maximum here about the close of the present century. If this estimate should prove correct, and the period of decrease should be as long as that of increase, the time required for the declination to pass from a minimum to a maximum and to return to the minimum, will be about two hundred and forty or two hundred and fifty years. We have not, however, at present, sufficient data to determine this period with accuracy, nor are the causes which produce the change well known.

The amount of the secular variation is very different in different parts of the earth. At the Cape of Good Hope, in two hundred and forty-six years, ending 1850, the declination had changed from $30'$ east to $29°\ 18'.8$ west, and was at that date slightly increasing. This shows a longer period and much greater change than in the United States. In New

England the whole change is probably between 6° and 8°. The following declinations, copied from the United States Coast Survey Report for 1855, were observed at Cambridge, Mass., and show the change at that place since 1708:

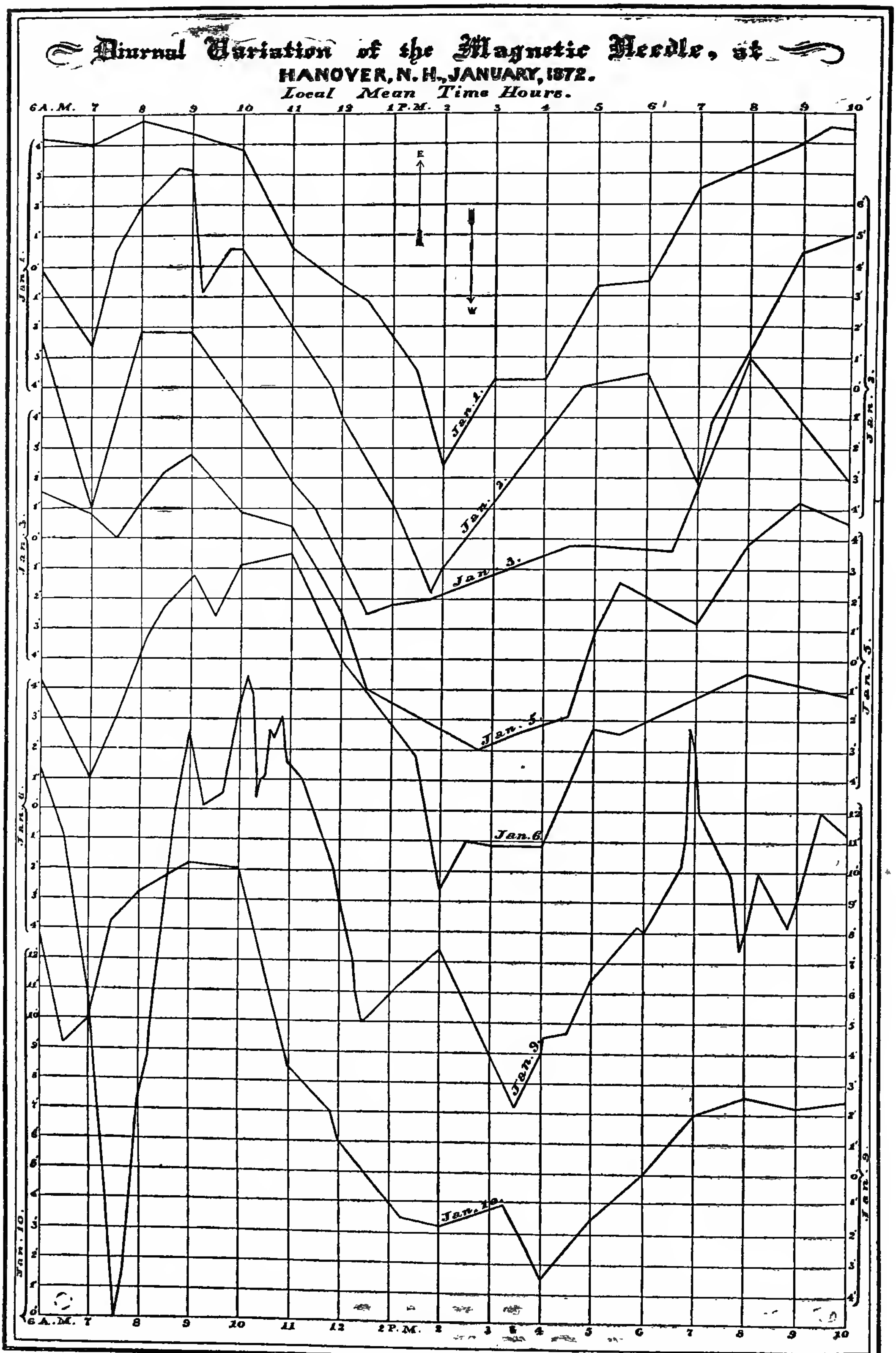
1708—9° 00′ west.	1782—6° 45′ west.	1840— 9° 18′ west.
1742—8° 00′ west.	1783—6° 52′ west.	1842— 9° 34′.9 west.
1757—7° 20′ west.	1788—6° 38′ west.	1844— 9° 39′ west.
1761—7° 14′ west.	1810—7° 30′ west.	1852—10° 08′ west.
1763—7° 00′ west.	1835—8° 51′ west.	1854—10° 39′ west.
1780—7° 02′ west.	1837—9° 09′ west.	1855—10° 54′ west.

From these facts will appear the importance of recording, with the minutes of every survey, the declination of the needle at the time and place. To do this the surveyor must know the declination, which he cannot do without some trouble and labor. He must frequently try his compass by some well established meridian, which, if he cannot find already determined, he must locate for himself. Neither should he lose any opportunity to take the bearing of any old line whose former bearing he may find in the record of some previous, perhaps the original, survey. By continuing such observations, he will learn not only the amount of the declination at the time of the former survey, but, also, its rate of change, and the whole change that has occurred since the running of the old lines with which he has compared his needle; and he will thus gain information which will render his services invaluable in disputes relating to division lines.

3. *Diurnal change in the Declination.* If hourly observations be made upon the delicately suspended needle of a magnetometer, or, still better, if we use a self-registering instrument by which a continuous record is made of the changes in the direction of the needle, we shall notice a diurnal variation of the declination, in northern latitudes, substantially as follows: During the night the needle will be comparatively quiet; but at dawn of day the north end will move toward the east, and will continue this decrease of declination till about 8 o'clock A. M., when it will commence a westerly motion, and will come to its maximum west declination at about 2 o'clock P. M. It will then return toward the east until some hours after sunset, when it will again remain quiet till the next dawn. But while this is in general true, it must be taken with much allowance. In the first place, it must not be understood that the needle is stationary even at night, for it seldom, if ever, fails to show more or

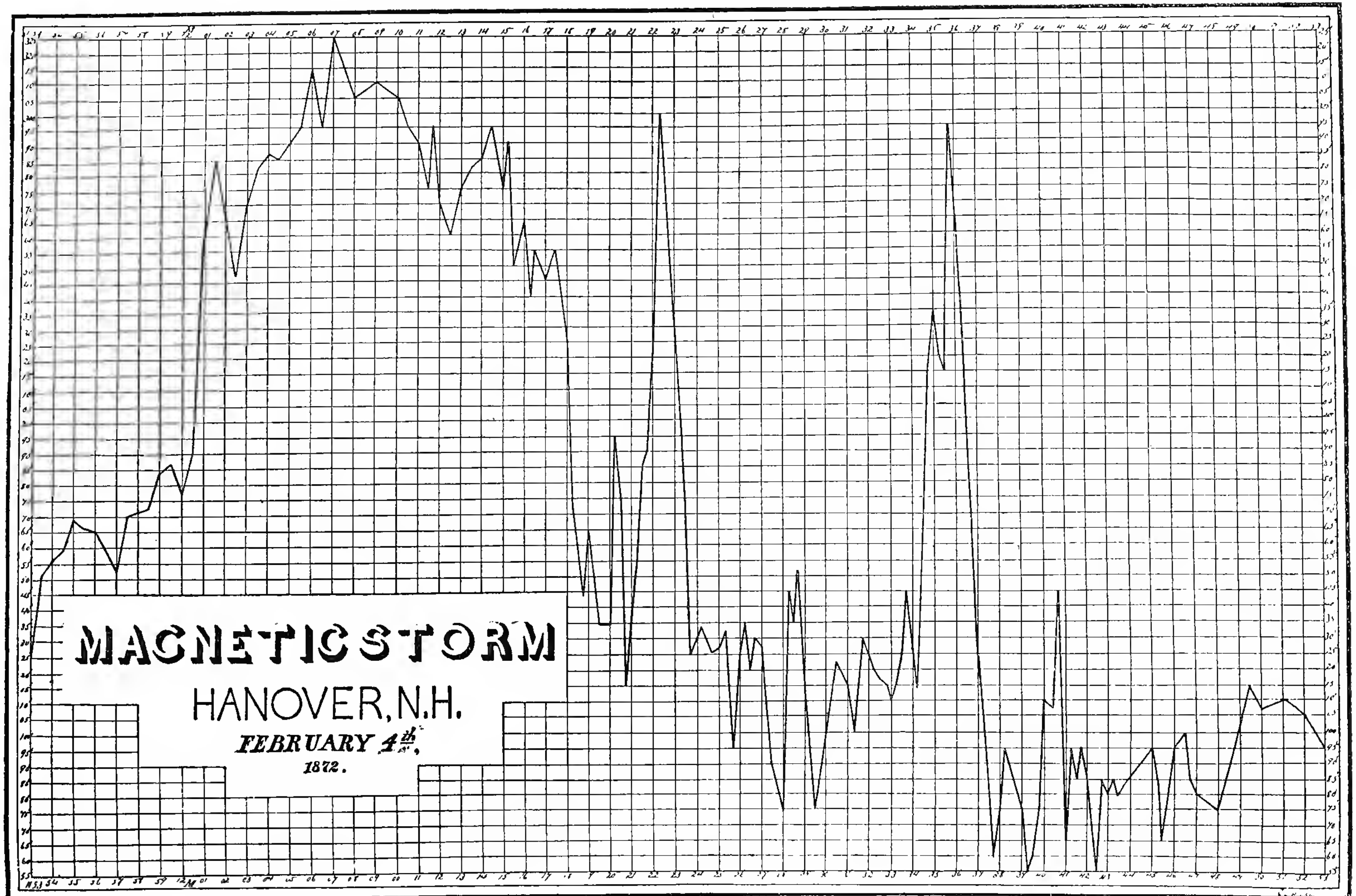
less change every hour of the twenty-four; but, ordinarily, the change is much less during the night than in the day-time. The extent of this variation is not the same in all places, nor on different days in the same place. It is greater in summer than in winter, and on clear days than in cloudy weather. At Hanover it is about 15′ in winter, and perhaps 20′ in summer. The morning deviation eastward from the direction during the night is usually about one third of the whole variation, or one half of the westward deviation from the same direction at 2 o'clock P. M. We give herewith a few curves showing the diurnal variation at Hanover, in January, 1872, from which a better idea can be obtained than from any verbal explanation. Of these curves we shall see that no two are precisely alike; and, if we should examine the curves for each day of the year, we should find the same variety that is observed in the weather of different days. In these diagrams, each curve has upon it the date at which it was observed. The vertical divisions indicate minutes of arc, and are numbered for Jan. 1 on the left hand, for Jan. 2 on the right, and so on, alternating for each day. Thus, while the zero line of each curve represents the same direction of the needle, a different line in each case is used for zero, to prevent confusion by the curves intersecting and blending together. A tendency of the curve upward indicates motion of the north end of the needle eastward, or decrease of declination, and downward indicates increase of declination. To determine, therefore, the relative pointings of the needle at the same time on any two of these days, compare each with its own zero. For example, at 2 o'clock P. M., on Jan. 1, the pointing was —6′.5; Jan. 2, it was —6′; Jan. 3, —2′; Jan. 5, —2′.4; Jan. 6, —2′.5, &c. January 9, it will be observed, was a day of considerable disturbance, and, at 2 P. M., the pointing was +7′.3, being from 10′ to 14′ farther east than on previous days; and the average pointing on that day and for several succeeding days was about 10′ or 12′ eastward of the usual direction of the needle. Of this we shall say more in speaking of magnetic storms.

4. *The annual variation of the Declination.* Besides the changes in declination already mentioned, there is an annual variation produced by the changing seasons of the year. This is perhaps so small as to be of little practical importance in the ordinary use of the needle, but it should not be omitted in a full discussion of the subject. Observations have


Diurnal Variation of the Magnetic Needle, at
HANOVER, N. H., JANUARY, 1872.
Local Mean Time Hours.
6 A.M. 7 8 9 10 11 12 1 P.M. 2 3 4 5 6 7 8 9 10
E
W
Jan. 1.
Jan. 2.
Jan. 3.
Jan. 5.
Jan. 6.
Jan. 9.
Jan. 10.

not been sufficiently multiplied to enable us to state with certainty the extent and manner of this variation for New England. Cassini began daily observations in Paris, in 1783, by which, in 1786, he was able to announce the discovery of this *annual variation.* By his observations it appeared that the westerly declination increased from June 20 to March 20, and from March 20 to June 20, decreased by about one third of the increase from June to March. Subsequent observations in other places do not fully confirm the results obtained by Cassini. It is more probable that there are two periods of retrogression, one between the vernal equinox and summer solstice, and the other between the autumnal equinox and winter solstice. This seems to be indicated by the observations of Gilpin, about the beginning of the present century, in England. But it is not necessary for our present purpose to pursue this part of the subject further, as this variation in New England is too small to require notice in the use of the needle, being probably less than one minute.

5. *Magnetic Storms.* Those irregular and occasional disturbances in terrestrial magnetism called magnetic storms, are generally attended by an aurora, and no doubt are one effect of the same cause which produces the aurora. They occur by day as well as by night, and therefore are not always accompanied by a visible aurora. Their duration and the amount of disturbance they produce are as varied as the features of our rain-storms. During a magnetic storm the needle is observed to be unsteady and tremulous, changing its direction, now this way and now that, to an extent dependent on the magnitude of the storm. Slight disturbances of this kind, affecting the direction of the needle by a few minutes, are not uncommon. The diurnal curve for January 9, 1872, shows such a disturbance. This disturbance continued through the night, beyond the limits of this diagram; and, as before stated, for several days after, the average pointing of the needle was some 10′ farther east than usual. There were also many other days of unusual disturbance during this month; and on the 4th of the following month a most remarkable storm was observed by the writer and his assistants at the Dartmouth College observatory. The day was cold and windy, the weather clearing after a heavy fall of snow. In the evening appeared that most remarkable aurora, covering the whole heavens south as well as north, which many will remember, and which was seen in Europe as


MAGNETIC STORM
HANOVER, N.H.
FEBRUARY 4th,
1872.

well as on this continent. The assistant in charge of the magnetometer noticed early in the forenoon of this day an unusual disturbance of the needle, and was thoughtful enough to make his observations every few minutes, and sometimes, at the height of the storm, every half minute, instead of the usual hourly observations. The annexed diagram shows this storm between $11^h\ 53^m$ A. M., and $12^h\ 53^m$ P. M. The vertical lines denote minutes of mean solar time, and the horizontal spaces are each $5'$ of arc. To compare the disturbance during this hour with the usual diurnal variation, as represented on page 14, it must be noted that if the former were represented on the same scale as the latter, it would appear to be nearly twenty-five times greater than here shown. The figures at the right and left margin are reckoned from a zero below the limits of this diagram, and which was the normal pointing when the needle was undisturbed. It will be noticed that, at $11^h\ 53^m$ A. M., the north end of the needle had moved eastward of its normal position $2°\ 05'$. This movement commenced about 10 o'clock, and went on with some irregularity up to the time when our diagram commences. From this time the eastward movement was more rapid, particularly after 12 M.,—from 12^h to $12^h\ 01^m$, increasing $1°\ 25'$. At $12^h\ 07^m$ the greatest eastward deviation was reached, which was $5°\ 25'$ east of the normal pointing. After this the westward motion was quite rapid, with considerable disturbance, however, and with two very marked and sudden fluctuations to the east, in which it reached, within $30'$, its maximum deviation. The most violent disturbances of this storm occurred within the hour here represented. After $12^h\ 53^m$ P. M., the needle became gradually more quiet, and by 3 P. M. had returned nearly or quite to its usual position. In the evening, during the remarkable display of aurora, though somewhat disturbed, the fluctuations were by no means so great as during the day. We cannot, of course, positively affirm that this aurora was not present during the day, but it seems more than probable that the needle is more affected by the approach than by the presence of an aurora, particularly of one like this, extending over the whole heavens. It would of course be impossible to use the needle in surveying at such a time, as by the sudden changes in the direction of the magnetic force it would be kept constantly oscillating. It must not be understood that during this hour the needle moved steadily back and forth as shown in the diagram, but it was

swinging sometimes 4° or 5°, and the pointings here indicated are the means of the two extremes of oscillation.

The Construction and Use of the Magnetic Needle. From the foregoing it will be easy to deduce the value of the magnetic needle in determining directions, and the precautions necessary in the use of it. In the first place, the greatest care must be exercised in the construction of the needle and its accompaniments. The most important points of construction are these:

1. *The magnetic axis of the needle should coincide with a line joining its extreme points,*—otherwise it will fail to indicate the true magnetic meridian. This would be of little consequence in using a single needle, but, in comparing the work of different needles, as must frequently be done, it becomes important. The magnetic axis of a needle may be determined by suspending it in a stirrup by an untwisted fibre of silk—first one side up and then the other—and observing the pointings in each position. This test should be applied by the maker of the needle, and the magnetic axis be made to coincide with the axis of the needle.

2. *The suspension of the needle should be such as to reduce friction to a minimum.* Since that component of the magnetic force, which tends to bring the needle to the magnetic meridian, diminishes as the sine of the angle the needle makes with that meridian, it will require but little friction to cause it to stop so far out of the meridian as to introduce an appreciable error into the results. The best compass needles are poised upon a fine needle point, in an agate or other jewelled socket; but with such a needle no less care is requisite to keep it than to make it right. The more delicate the point, the more liable it is to injury, and it can be kept in proper condition only by raising the needle from it when the compass is moved, and letting it down carefully when to be used. The arrangement for raising the needle should be a screw and not a cam, as the latter is liable to work loose in transportation, and allow the needle to fall upon the point.

3. *The compass-box and tripod should be free from everything magnetic.* Not only should no iron be used in their construction, but the brass for the compass-box and tripod-head should be tested to determine whether it has any power of attracting the needle. In two instances known to the writer, the brass of a compass-box has become so magnetic as to destroy the value of the instrument. It is easy to determine whether such

is the case, by directing the sights to various objects in different directions, reversing on each, and noting whether the needle gives a different reading by any of the reversals. If the reading is not changed by reversing in any of the positions, the box may be considered free from magnetic power.

4. *The pivot should be exactly in the centre of the graduated circle,* that the two ends of the needle may give the same reading. It is true this error may be eliminated by reading both ends, and taking the mean; but it is better to have no error to eliminate. If, however, the two ends do not read alike, the mean reading should be used.

5. *In using the compass, proximity to all magnetic substances, both natural and artificial, must be avoided.* Masses of iron, like gas- or water-pipes, water-conductors, and lightning-rods, are a source of disturbance not easily avoided in cities; and the water-conductors and lightning-rods being placed vertically are more disturbing than larger masses lying horizontally. The reason of this is that, having their longer axis more nearly in the direction of the force of terrestrial magnetism, they become magnetic by induction, and act not merely as so much iron, but as magnets. They must therefore be given a wide berth by the surveyor with the magnetic needle. In making observations with the magnetometer, it is thought necessary to remove from such objects to a distance at least equal to twice their height; but it is probable that no perceptible influence upon an ordinary needle would be observed at half that distance.

Besides these larger masses of iron, the surveyor sometimes carries upon his person the cause of much error. Ordinary knives, if not brought nearer to the needle than two or three feet, will have no appreciable effect, but magnetized knives should be kept at a greater distance; and the chain-men should not be allowed to bring the chain within less than twenty feet of the instrument. There is another source of disturbance, carried by the surveyor himself, which frequently he does not suspect. It is the common buttons, with an iron body, used upon coats. In reading the bearing, these are likely to be brought near to the needle, and to produce considerable deviation. Such buttons ought not to be worn in working with a compass.

Still more difficult is it to avoid local attraction by magnetic rocks, which are more common than is generally supposed. Indeed, so common

is this source of error, that in every case the bearing of a line should be taken at two places at least, and these should be as far apart as possible. If the two bearings agree, it may be safely concluded that they are correct, and not affected by local attraction. Yet it must not be forgotten that it is possible, though highly improbable, that two bearings thus taken should be equally affected. If the line is very short, or if no two points on it can be found at which the bearings agree, a point may be taken out of the line in any direction, and at a suitable distance; and, if the direct and reverse bearings from it to any point of the line be found to agree, those points may be considered free from local attraction. In some places, as in the vicinity of iron mines, it will be found impracticable to use the needle at all for the determination of bearings; but even in this case, the figure and area of a field may be found by so placing the compass at each angle as to take the bearings of the two adjacent sides from the same point. This will give the angle between these sides without error from local attraction.

The most difficult problem ever presented to the surveyor is that which asks him to retrace a lost line, with but one point known, and the bearing from some old deed. To add to his perplexity, the parties in interest are usually too much excited by the apprehension of being robbed of a square rod of rocky pasture, or of swamp rich in mud and brakes, to be able to give correctly such facts as might be serviceable in the solution of the problem. In such case, if the parties cannot be induced to agree upon a second bound and thus determine the line, there is no way but to "*run by the needle*," after making due allowance for change in declination since the previous survey. Running in this way may lead to the discovery of some old landmark, nearly obliterated, and thus settle the dispute; but if not, though the error in the bearing is likely to be 15′ to 30′, it is *better than a lawsuit;* and if, in such case, the parties in their ignorance believe that to be "true as the needle to the pole" is to be true enough it is certainly an occasion where "'tis folly to be wise."

Determination of a true meridian. That the surveyor may be able to test his compass by some well established meridian, it would be an economical measure if the state should locate and permanently mark a true meridian in one or more of the principal towns of each county, and then require by law all surveyors to record the declination with the

plan or report of every survey, stating at what time and by which of these meridians the declination was taken.

In the absence of such meridians located at the public expense, the surveyor may, with little trouble, determine one for himself. The remainder of this paper will be devoted to an explanation of some of the methods by which the astronomical meridian of a place may be found.

1. *By observations upon the pole star* (Polaris). This star has now (Jan. 1, 1874) a polar distance of 1° 21′ 45″, with an annual diminution of 19″, and it may be observed either at its culmination or elongation, or at any other known time. The time selected for the observation must depend on the circumstances of the observer. If he has not the means of determining his local time within fifteen seconds, he must take the star at its elongation; but if he can know the time, he may observe whenever it is most convenient to himself. The culminations offer the advantage of giving the meridian at once, without computation or correction for azimuth; but neither at the culmination nor at the elongation can double observations be taken to eliminate any error in the adjustment of instruments, and if the single observation be missed at the moment, it cannot be repeated till the next night. It may therefore be more convenient to observe without reference to these; but in that case the local time must be known, the azimuth of the star computed, and the proper correction applied.

These observations may be made with a theodolite or transit, or, for want of these, we may use simply a plumb-line, with a compass-sight, or anything with a small hole in it to look through. Any heavy body suspended by a string will serve for a plumb, and it may be suspended in water to give it greater stability. It should not, however, even then be used in any considerable wind, as this will cause it to deviate from a vertical. South of the plumb-line, and at a convenient distance, fix a board firmly in a horizontal position, upon which a small piece of board, with a compass-sight affixed, may be moved east and west. Bring this in line with the star and plumb-line, and follow the star until the time of culmination, then fasten the compass-sight, and the meridian is secured. Or, if the time of an elongation be selected for the observation, bring the compass-sight into line a little before the time, and follow the star till it begins its return. This line, with the proper correction for azimuth, will be the true meridian. So, also, if the observation be made at any time

(the time being noted), and the proper correction applied, the true meridian will be determined.

If a transit or theodolite is used, it must be carefully adjusted, or the results will be less reliable than by the simple plumb-line, as above. The adjustments liable to affect the work are the collimation, and the height of Y's or horizontality of the axis of the telescope. By making two observations,—one with the telescope reversed, and using the mean result,—any error which would otherwise occur by defect in these adjustments is eliminated; but in this case both observations cannot be taken at the moment of culmination: hence, for one, at least, the azimuth must be computed. If neither is taken at the culmination, separate azimuths must be computed for each.

Unless an instrument with a perforated axis for illumination of spider lines is used, some easily managed means must be contrived for this illumination. If a steady light cannot be thrown upon the lines in such way that it may be increased or diminished at pleasure, it is not easy to see both the star and lines with that distinctness necessary to a good observation. With the perforated axis there is little difficulty in securing the right amount of light; but without this, the light must be thrown into the object end of the telescope. This can be done successfully by using a stand to carry a bull's-eye lantern, and a vertical piece of board covered with white paper to serve as a reflector, the diffused, reflected light being much better than the direct rays of the lantern; or, a ring of thin white paper, of suitable size to cover the outer edge of the object glass, leaving the centre open, may be made to adhere to the glass by simple wetting, which will serve to reflect and diffuse the light thrown upon it.

To mark the meridian after the observation, a piece of board with a small hole, behind which a light is placed, will serve as a temporary arrangement. This need not be placed precisely in line of the meridian, but being fastened, before observing, at some point near this line, the angle between it and the star may be taken, and the work of fixing and permanently marking the meridian be deferred to any convenient time. When the final marking is done, it should be such that neither frost nor any other natural causes will disturb it.

2. *A meridian may be established by observations upon the sun;* but, while they offer the advantage of the day-time for doing the work, they

are not, on the whole, so convenient as the use of the pole star. One objection to them is, that, as the centre of so large a body cannot be accurately observed, it is necessary to observe the limb or edge; and thus a computation is necessary to reduce to the centre, or a second observation must be made on the opposite limb to eliminate the error. Hence, in no way can a meridian be directly found by solar observations without computation and correction for azimuth, except by the rough and unreliable method of guessing at the sun's centre when on the meridian. These observations require, also, the use of a telescope with a darkened glass, which is not always at hand. The most convenient way of locating a meridian by the sun is to take its altitude in the morning or evening, when the altitude is rapidly changing, and measuring the angle between it and some fixed mark. The azimuth of the sun may be computed by data found in the nautical almanac, whence the azimuth of the mark becomes known, and the meridian is determined. By this method, double observations must be made to eliminate the error of taking the limb instead of the centre, and, also, by reversing the telescope, to eliminate error in collimation and height of Y's, and in the position of the zero of the vertical circle. In one observation, bring the sun into one angle of the spider lines and tangent to each; then read the horizontal and vertical circles; point to the mark, and read the horizontal circle; reverse the telescope, and take the sun in the same manner as before, but in the opposite angle,—that is, upon the opposite side of both lines; read the circles again, and observe the mark as before. It would make the work still more sure to take a second set in the other angles of the lines, but this is not essential. The mean azimuth of the mark, as obtained by the different observations, will be its true angle with the meridian.

If the local time is known and noted with each observation, the azimuth of the sun may be computed without observing its altitude; but it is easier to observe the altitude than to find the time. To take the sun, when on the meridian, will also require the time with a correction for the difference between apparent and mean time. Much better than these solar methods, will be found the following:

3. *By observations upon any one of the stars.* Select some bright star, as Sirius or the planet Jupiter, that, if possible, the spider lines may be seen without artificial illumination. If this can be done, it will save the

trouble of adjusting a light for this purpose. With a theodolite having a vertical circle, which has been previously adjusted with care and firmly set (as in all these observations the instrument should be), take the star at least three hours before its culmination, recording its altitude and the angle it makes with the mark; reverse the telescope, and observe in the same way again. Note, also, the time of each observation with sufficient accuracy to be ready for the star at the same altitude after culmination. Before the star descends to this altitude, set the vertical circle to that altitude, with the telescope in the same position (direct or reverse) as when the observation at the same altitude was made before culmination, and, as soon as it can be done, bring the star into the field by turning only the horizontal circle; put the vertical line upon the star, and follow it till it comes to the intersection; read both circles, and observe the mark; reverse the telescope, set to the other altitude, and observe the star, and mark again in the same manner. Find the mean angle between the star and mark by the first set of observations taken before culmination, and, also, by those taken after; and the half difference of these two angles will be the angle between the mark and meridian. By this method of equal altitudes, all trouble of finding the exact local time, and of computations, is avoided.

It remains only to give the formulæ for computing the azimuth of the pole star,—1. When taken at its elongation; and, 2. When taken at any other time.

1. Let $p =$ the polar distance of the star.
$l =$ the latitude of the observer.
$z =$ the required azimuth.

Then we have

$$\sin z = \frac{\sin p}{\sin l}$$

when taken at the elongation.

2. Using the same notation as above, with the addition of $t =$ the time since the last culmination reduced to degrees, &c., of arc, we have

$$\cot z = \frac{\cos(l + k) \cot t}{\sin k},$$

in which

$$\tan k = \tan t \cos p,$$

when the observation is not at the elongation.

NOTE. Inasmuch as this chapter explains satisfactorily the proper way of using the magnetic needle, I take occasion here to say that all the courses mentioned subsequently in this report may be understood as referring to the true meridian. They were taken with pocket compasses originally, and have been corrected according to the principles stated so lucidly by Prof. Quimby. C. H. H.

CHAPTER VII.

TOPOGRAPHY.

THE general shape of the territory of New Hampshire is that of a scalene, almost a right-angled triangle,—having the perpendicular one hundred and eighty, and the base seventy-five miles long. From the crown monument, at the extreme north point, to the south-east corner of Pelham, at the most southern extension, the distance is one hundred and eighty miles,—the length of the perpendicular. The longest distance that can be measured in the state is from the crown monument to the south-west corner, a distance of one hundred and ninety miles, and this line would be the hypothenuse of the triangle. The greatest width of the state is from Chesterfield to the outer island of the Isles of Shoals, a distance of one hundred miles. To the outermost projection of Rye from Chesterfield, the distance is seven miles less. At Colebrook, the width of the state is only twenty miles.

New Hampshire is bounded north by the province of Quebec, east by the state of Maine, south-east by the Atlantic ocean and Essex county, Mass., south by the state of Massachusetts, west and north-west chiefly by the state of Vermont, and partially by Quebec. It lies between 70° 37′ and 72° 37′ longitude west from Greenwich, and between 42° 40′ and 45° 18′ 23″ north latitude.

The books usually give the area of the state as 9,280 square miles. Mr. Warren Upham carefully measured the area of the state upon J. R.

Dodge's map, published in 1854, and finds it to be very nearly 8,818 square miles, although the explanations in the margin state the figure to be 9,280. The scale given on this map is evidently incorrect, perhaps on account of the usual want of correspondence between an original draft and the printed sheet. Hence I have had the area carefully measured upon the original draft of our new map, or the one which appears in the accompanying atlas, and find it to be 9,336 square miles.*

Our territory possesses a mountainous character, much more so than the average among the states along the Atlantic slope of the continent. It is situated about a third of the way from the north-eastern end of the Atlantic system to the south-western extremity of the chain. Viewed as a whole, there are two culminating points in this system. The land rises gradually from the ocean level in the Gulf St. Lawrence till the apex of the White Mountains is reached. Then it falls to the Hudson river, reaching the ocean level along that valley. From this line it ascends to the mountains in western North Carolina, whence the land descends to the Gulf of Mexico.

More particularly, there is a mountainous ridge following the eastern rim of the Connecticut river basin entirely through the state. On the east the country is low, scarcely rising above five hundred feet for three fourths of the area outside of the foot hills of the White Mountains. These mountains occupy nearly all the space east of the western ridge to the Maine line, for a distance north and south of about thirty-three miles. This district is mostly wooded, very mountainous, and scarcely inhabited. Deep transverse valleys divide the White Mountains proper from a similar triangular area between the Androscoggin and Connecticut rivers. There is a third mountainous district half way through Coös county, and the fourth and last along the extreme northern boundary. On the other

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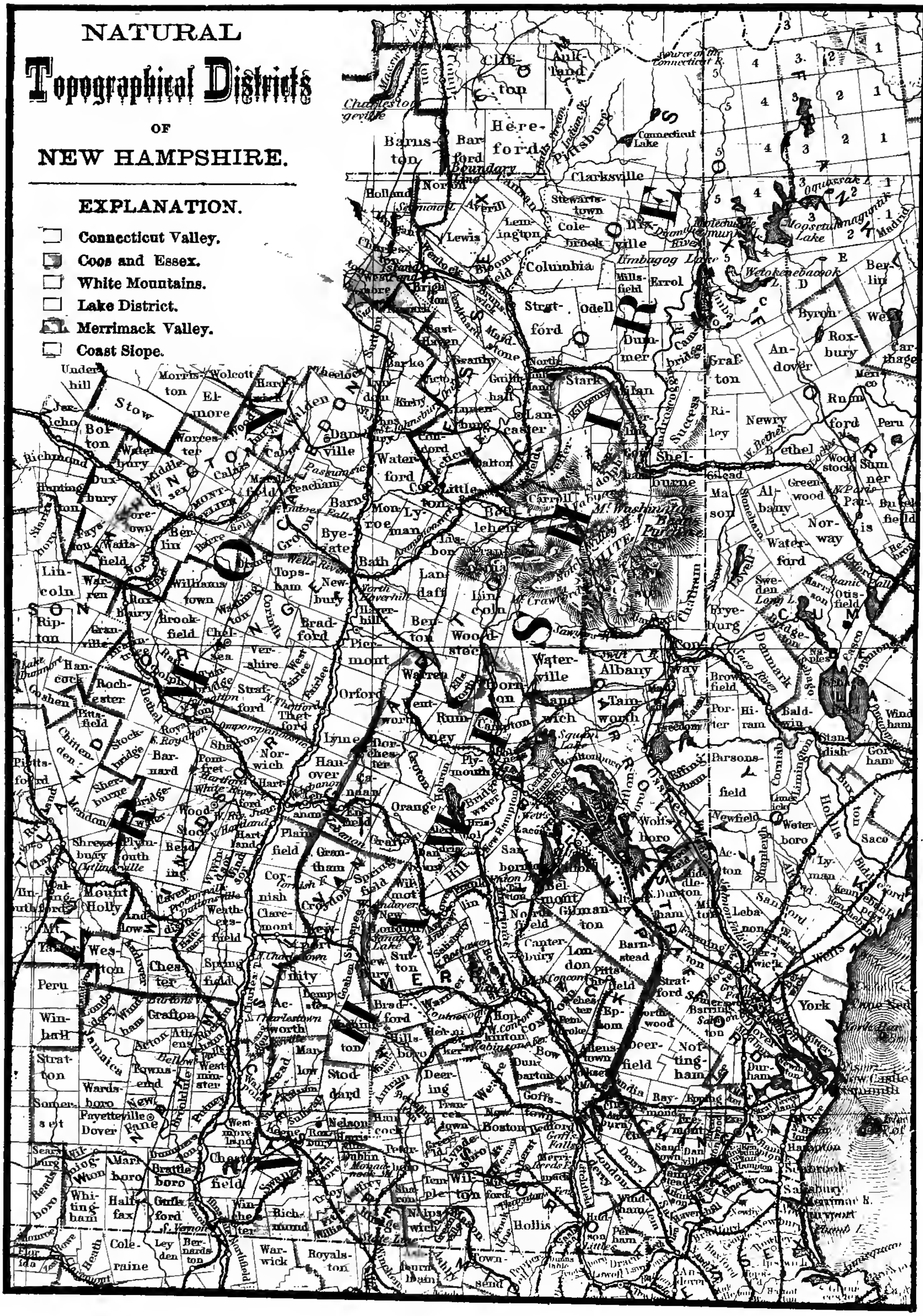
* The calculations were made by Mr. T. B. Mann, of Boston. There are two or three points in connection with the calculation that need to be mentioned. The proper west line of New Hampshire is the west side of Connecticut river. At the mouth of the Passumpsic, where the Connecticut has three channels, the calculation has omitted the narrow channel, and a large island next to the Vermont side. In Portsmouth harbor, no islands outside of Newcastle are included. The centre of Salmon Falls river and the ponds between Wakefield and Portsmouth harbor was regarded as the east line of the state. At Seabrook and Rye, the measurement includes the bays at the mouths of rivers, running from headland to headland. The Isles of Shoals are not included, which do not seem to cover more than one square mile. If to this figure we add a square mile for the neglected channel in Monroe, and 54 miles for the belt of three miles of ocean over which our authorities exercise jurisdiction, the total area may be stated at 9,392 square miles.


NATURAL
Topographical Districts
OF
NEW HAMPSHIRE.
EXPLANATION.
Connecticut Valley.
Coos and Essex.
White Mountains.
Lake District.
Merrimack Valley.
Coast Slope.

side of the Connecticut there is a similar elevated country, constituting the sparsely settled district of Essex county, Vt. In mineral features this is like the White Mountains, and should properly belong to New Hampshire, if the boundary line between us and Vermont were at all symmetrical. As it is topographically connected with our state, I shall take occasion to refer to it often, and to describe it, so far as may be practicable, considering its extra-limital position, and the scantiness of our information concerning it. Our survey has done something towards its exploration, though by no means so fully as is desirable.

The area of our field of exploration may be divided into six districts, each of which will be described in detail. They are the topographical divisions that suggest themselves most naturally.

1. *Hydrographic basin of the Connecticut river*, leaving the main valley at Barnet, and continuing up the Passumpsic to its source.

2. Hilly district of the principal portions of *Coös county, N. H., and Essex county, Vt.*

3. *White Mountain area.*

4. *Winnipiseogee Lake basin.*

5. *Merrimack River basin,* wedging into the White Mountain area.

6. *The Atlantic slope in Strafford and Rockingham counties.*

These districts present themselves forcibly to the eye upon the accompanying map.

Before describing these topographical areas, it will be well to understand what are the artificial boundaries of New Hampshire.

The Northern Boundary.

The northern boundary of the state has been more carefully measured than any other, having been surveyed under orders from the United States government, for the purpose of marking the line of division between New Hampshire and Canada, in accordance with the treaty of Washington bearing date of August 9, 1842. It is needless here to state the particulars of the controversy which led the commissioners to fix upon the present as the proper boundary line. The two countries were much excited previous to the decision, so much so as to talk of settling the dispute by fighting. An elegant series of maps, upon the scale of one mile to two inches, of the country from the head of the

St. Croix river in Maine to St. Regis on the St. Lawrence river, may be found in the state library at Concord, which was prepared from very elaborate surveys after instructions from Major J. D. Graham, of the United States topographical engineers, principal astronomer, who acted under the direction of congress. Two stations along the New Hampshire boundary were determined astronomically by Major Graham. One of these is situated at the extreme east point of Vermont, on the west side of Hall's stream, having the latitude of 45° 0′ 17″ .58, and the longitude west from Greenwich of 71° 30′ 34″ .5. The other is about half a mile N. 10° W. from Lake Sophy, or Third Connecticut lake, having the latitude of 45° 14′ 58″ .06, and the longitude west of Greenwich of 71° 12′ 57″. Distances and bearings were measured carefully by chaining and triangulation. The trigonometrical work seems to have been performed under the guidance of different engineers,—all east of Mt. Prospect, an azimuth station about half a mile north-west from the small Fourth lake, having been under the direction of Lieuts. Emory and Raynolds, of the U. S. topographical engineers, while that on the west was surveyed by A. W. and S. Longfellow, civil engineers. In brief, the line may be described as following the water-shed between the St. Francis and Connecticut rivers, from a point at the junction of Maine, New Hampshire, and Quebec province, to the head of the main Hall's stream; thence down Hall's stream to the first named astronomical station of Major Graham. It is hence often styled the "highland boundary."

More particularly, the boundary may be thus described: The point to which the three territories converge is known as "Crown monument," or No. 474, from the first at the head of the St. Croix river, and appears to be in latitude 45° 18′ 23″ .33; longitude 71° 5′ 40″ .5. This is on high land, and the country descends to the next post, or No. 475. Monuments are located at most of the prominent elevations and depressions, as the line is traced westward. Monuments 474 to 477 lie along the head waters of the Magalloway (*Margalloway*, as spelled by the commissioners and Carrigain's map). No. 478 seems to be situated upon rising ground not specially connected with either stream; but from No. 478 to No. 484, we travel along the little streams discharging into the valley of Lake Sophy. The whole of the Perry stream basin lies between Nos. 484 and 485,

which is not a great distance. Nos. 483 and 484 lie close together, and are exactly north of the astronomical station near Lake Sophy. The country sloping towards Indian stream extends from monument No. 485 to No. 500. No. 489 is near the point of a curious northerly projection into Quebec. Nos. 501 to 506 are on the slope of Hall's stream. No. 506 is exactly on the head of the main Hall's stream, and is flanked closely by Nos. 505 and 507. Nos. 508 to 517 lie at intervals along Hall's stream to the east end of the north line of Vermont. The total length of the north boundary line is 110 miles, but a direct course between the extreme points is 32.7 miles. The monuments are of iron, having on them the names of the U. S. and H. B. M. commissioners. The line itself was carefully bushed out by the surveyors as wide as an ordinary highway, and the trees have not yet grown up again,—so that the course of the boundary is still conspicuously marked.

The topographical features are carefully laid down along the whole line. That west of Hall's stream, in Vermont, appears to have been projected by new surveys in 1851, by Lieut. Thom, U. S. Engineers. Monument No. 522 lies just west of Leach Branch, in Canaan, Vt. Farther west, Barnston Pinnacle, a very conspicuous granitic ledge, is said to rise about 600 feet above the lake at its base. The earlier surveys seem to have been made in 1845. The line is copied as accurately as possible upon our largest map. Mr. Huntington has written something concerning the altitudes of this highland boundary, in his sketch of the topography of Coös county.

Description of the Eastern Boundary of New Hampshire.

By J. H. Huntington, Commissioner on the part of New Hampshire to mark anew the boundary between New Hampshire and Maine.

The eastern boundary of New Hampshire was for many years a matter of fierce controversy. One reason of this, no doubt, was owing to the fact that the geography of the country was little known; besides, the same territory was granted to several different parties, both by the king of England and the council of Plymouth. It was finally determined by commissioners appointed by the king. Their report was as follows: "As to the northern boundaries between said provinces, the court resolve and

determine that the dividing line shall pass up through the mouth of Piscataqua harbor, and up the river Newichwannock, part of which is now called Salmon Falls, and through the middle of the same up to the fartherest head thereof, and from thence north two degrees westerly, until 120 miles be finished from the mouth of Piscataqua harbor aforesaid, or until it meets his majesties other governments; and that the dividing line shall part the Isles of Sholes, and run through the middle of the harbor between the islands to the sea on the southerly side, and that the south-westerly part of said islands shall lye in and be accounted part of the province of New Hampshire." To the order of Governor Belcher, appointing Walter Bryent to survey the line, was affixed the following memorandum: "The true north 2° west is by the needle north 8° east, which is your course." Bryent went only to the Saco, and it is supposed that the line was extended to the north-east corner of Shelburne, in 1763, under the direction of Isaac Rindge. From this point the survey was continued, under the direction of a committee of the legislature, to the birch tree that formerly marked the northern terminus of the line,—the work having been done by Jeremiah Eames and Joseph Cram.

After the lapse of many years, when Maine had been erected into a separate state, provision was made by the states of New Hampshire and Maine to have the line resurveyed, and designated by suitable monuments. Hon. Ichabod Bartlett, of Portsmouth, and Hon. J. W. Weeks, of Lancaster, were appointed commissioners on the part of New Hampshire.

In 1858 the line was again surveyed. Col. Henry O. Kent was appointed on the part of New Hampshire.*

The northern terminus of the eastern boundary of the state is on the water-shed between the streams flowing northward into the St. Lawrence, and the streams that flow southward and form the Magalloway. The iron post that marks the north-east corner of the state is also on the boundary between the states and the provinces, and the point is said to be 2,569 feet above the level of the sea.

The line between New Hampshire and Maine runs south 2° east.

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* Since penning the above, Mr. Huntington has attended to his official duty of remarking this boundary line, in the month of April, 1874.
C. H. H.

For the first fifteen miles there is an unbroken primeval forest; then for seven miles it is still a wilderness, but in New Hampshire all the large timber has been taken off by lumbermen; thence southward, clearings alternate with the forest until we reach Chatham, whence southward the country is settled. At first the descent is quite rapid, but, on reaching the branches of the Magalloway, for several miles the country is comparatively level. But it soon rises, and we pass over Mt. Abbott, and here we touch the water-shed between the Connecticut and the Magalloway; and this is the only point where it reaches the line of Maine. Leaving Mt. Abbott, the line descends somewhat, but in a mile and a quarter it reaches the summit of Mt. Carmel, which is the highest point on our eastern boundary. South from Mt. Carmel the line crosses several branches of the Magalloway, passes over Prospect hill, and the next stream of any considerable size is the Little Magalloway. From this stream the line passes over a ridge of Bosebuck mountain, and on on the southern border of the Academy grant it crosses Abbott brook. Along the border of the Academy and Dartmouth College grants the contour of the line is very irregular, but Half Moon mountain is the only noticeable height. South of this mountain the line crosses an open bog, and near the mouth of the Swift Diamond it twice crosses the Magalloway river, and it crosses it a third time near the north border of Wentworth's Location. In Errol it crosses Umbagog lake, touching two points of land on the eastern shore. On the border of Cambridge, the first town south of Umbagog lake, the line crosses the Hampshire hills, and several branches of the Androscoggin. In Success it crosses the Chickwolnepy, then runs along the western slope of Goose Eye mountain, passes over Mt. Ingalls, and then on the border of Shelburne it descends to the Androscoggin. Southward it crosses a ridge of land, and two miles and four tenths from the Androscoggin it strikes Wild river; then with varying undulations it rises until it reaches the summit of Mt. Royce, whence the descent is very precipitous to the open country on Cold river, in Chatham and Stow. The boundary follows the valley of this stream below Chatham centre, and on the south line of Chatham it crosses Kimball pond, and leaves only a small part of it in New Hampshire. In Conway it crosses the Saco, thence passes over a gently undulating country, except that there is quite a hill just before it crosses the

Ossipee river on the border of Freedom. Southward, except its lakes, the country has no striking characteristics. The line touches Province pond, that lies principally in Effingham and Wakefield, and in the south part of the latter it strikes East pond, which is the source of Salmon Falls river, and this is the boundary to the ocean. From the mouth of the river the line runs along the main channel, and divides the Isles of Shoals into unequal parts. The largest area, including Appledore and Smutty-nose islands, belongs to Maine; but Star island, which has the chief population of the islands, belongs to New Hampshire. The boundary line passes between Smutty-nose and Cedar, which are practically one, and Star island. J. H. HUNTINGTON.

WESTERN AND SOUTHERN BOUNDARIES.

There has been no end of dispute respecting the southern boundary line. The south-eastern portion is made to average the distance of three miles northerly from the Merrimack river for about thirty miles. From a fixed point, a "pine tree" between Pelham, N. H., and Dracut, Mass., five and one fourth miles east of the Merrimack, there commences a line running directly to Connecticut river, with the course N. 86° 59′ 37″ .5 W. The distance is about fifty-eight miles. According to a plan in the state library, the distance between the south-east corner of Hinsdale and a due east and west line starting from the pine tree and ending on the west bank of Connecticut river, is 942 rods. The difference between the true and magnetic meridian is given as 6° 20′ 30″. The plan was drawn by E. Hunt, from a survey made August, 1825.

The western boundary of the state has been fixed at low water on the west bank of Connecticut river as far as the north-east corner of Vermont. Above that point the small Hall's stream separates the state from the province of Quebec.

ELEVATIONS ALONG THE BOUNDARIES OF NEW HAMPSHIRE.

Height of tide at Portsmouth is 8.6 feet; the mean or half tide is, in all cases, the datum to which our altitudes refer. Head of tide in branches of the Piscataqua is at Exeter, Dover, and South Berwick.

	Height in feet.
Great Falls, top of dam,	166
Three Ponds, Milton,	409

Horn pond, Acton, Me., (Wells)	479
North-east ponds, "	499
Highway crossing by Saco river, ...	451
Grand Trunk Railway, ...	713
Umbagog lake, ...	1256
Mt. Carmel, ...	3711
Crown Monument, ...	2568
Near Magalloway pond, ...	2812
North-west head of Magalloway river, ...	2917
Gap near Lake Sophy, ...	2146
Mt. Prospect, ...	2629
Hall's Stream bridge, Vermont line, ...	1098
Bridge, West Stewartstown, ...	1054
Railroad bridge, North Stratford, ...	915
Top of Fifteen-miles falls, at crossing of P. & O. Railroad, Dalton, low to high water, ...	832–836
Connecticut river, just below Lower Waterford bridge, high water, . . .	643
" " at foot of McIndoe's falls, ...	432
" " at Wells River, low water, ...	407
" " at Hanover, ...	375
" " at White River Junction, low to high water, . . .	330–352
" " at Windsor Railroad bridge, ...	304
" " at Beaver Meadow, Charlestown, ...	289
" " at foot of Bellows Falls, ...	234
" " at head of Stebbins island, Hinsdale,.	206
Descent from Connecticut lake to this point, ...	1412
State Line station, Cheshire Railroad, ...	898
Merrimack river at state line, ...	91

Topographical Districts.

I. *The Connecticut Valley.* The limits assigned to this district differ from the exact area drained by the waters of the hydrographic system of the Connecticut. Owing to the presence of a prominent mountain ridge six or seven miles back from the river, the proper valley lies in the western part of the east side of the basin. This boundary corresponds, also, with that of the distinctive agricultural and geological character of the district. In general, it follows on the east line of the ridge of slaty or quartzose hills from Winchester to Benton, and thence the eastern line of the Connecticut basin to Carroll; thence it continues down the

John's river valley to the Connecticut in Dalton, crosses over the Concord, Vt., ridge to the eastern line of the Passumpsic river basin, which it follows around to Newark, Sheffield, and Cabot. From here the line coincides with the west border of the Connecticut basin to Washington, Vt.; thence it proceeds west of south directly to Proctorsville, Vt. Here it turns back sharply to the south-west corner of Hartford, whence it proceeds again nearly in a right line west of south to the Massachusetts line in Halifax, Vt. This area comprises about 3,200 square miles, and it is the best agricultural district east of the Green Mountains.

Hinsdale and Vernon combined—the southern border towns of this district—make a natural basin about seven miles in diameter. Hinsdale is not over half a mile wide at its southern extremity. On the east bank of the Connecticut, Foxden mountain bounds the district as far as the village of Hinsdale. Here the Ashuelot has cut a deep, narrow chasm into the range. The high land continues to the north, culminating along the north town line, in Wantastiquit or Mine mountain, more than 1,000 feet above the Connecticut. The more eastern part of this mountainous pile is called Daniel's, and East mountain, and Bear hill. A spur runs down opposite Brattleborough village, about a mile and a half, close to the river's bank. As seen from Brattleborough, Wantastiquit mountain is rough and precipitous, barely giving a foothold for trees.

On the Vernon side the range commences directly at the South Vernon Railroad junction, and follows the state line westerly to its culmination in the south-west corner of the town, perhaps 700 feet above the river. Then it sweeps around, and pursues a northerly course into Brattleborough.

Although one might fancy this basin an extinct volcanic crater, it was not this resemblance which led a few persons, near the close of the eighteenth century, to imagine Wantastiquit mountain an active volcano. The supposed volcanic phenomena were described fully in the Transactions of the American Academy of Arts and Sciences, Boston. Dr. Timothy Dwight also visited the locality in 1798, and seems to have regarded the phenomena as "in a very humble degree volcanic." The site of the supposed eruption is about one hundred and fifty feet below the summit. A loud noise had been heard, and on this spot a black iron ore, much like scoria, seemed to have been thrown about. From an

excavation, iron ochre and the "vitrified ore" were obtained in considerable amount. The noise probably came from the decomposition of pyrites, while the ores are such as slightly resemble artificial slag, though formed by concretion or segregation from moist clay.

The high land continues through Chesterfield, Westmoreland, and Walpole,—cut down to 830 feet in Westmoreland for the passage of the Cheshire Railroad, and to the level of the Connecticut just below Bellows Falls. On the Vermont side the slate range of Guilford has been cut through by West river in Brattleborough and Dummerston. Just to the north there is the conical granitic peak of Black mountain, which is the culmination of the hilly ridge from Bellows Falls. Both the Vermont and New Hampshire ridges close in at Bellows Falls, making Kilburn peak in Walpole. This is about 1200 feet high, and is more ragged and precipitous than Wantastiquit. It is an outlier of an older formation, upon which the slates were originally deposited, and then elevated so as to stand nearly upon their edges. Three streams have cut around this mountain; the Connecticut and Saxton's rivers on the west, and Cold river along its south-eastern slope. My father supposed the Bellows Falls gorge was worn out subsequently to the formation of the pot-holes in Orange, along the track of the Northern Railroad. The occurrence of the pot-holes, however, can be explained more simply otherwise.

The third of the basins is not quite so regular. On the east side there commences a series of mountains of quartz, in Charlestown, Acworth, Unity, Claremont, Croydon, Grantham, Plainfield, East Lebanon, Hanover, Lyme, Orford, and Piermont, into Benton. The basin may terminate in Cornish, opposite Mt. Ascutney. In Charlestown we have Page, Sam's, and Prospect hills. Perry's mountain makes a range between Unity and Charlestown, cut through by Little Sugar river. The land then rises into Fifield hill, Unity, and Bible hill, Claremont. At this point Sugar river valley intervenes, and carries the proper Connecticut slope farther east than the district under consideration. On the north the mountains increase their strength, and the long and elevated Croydon and Grantham range pushes on to the Mascomy lake in East Lebanon. Green and Bald mountains in Claremont are the foot hills of this range. Barber's mountain occupies a bend in the river in West Claremont. In Cornish, Parsonage, Smith's, Kenyon, and Dingleton

hills make a series of elevations crossing over towards Ascutney, the highest peak in the Connecticut district, and crowding the river.

On the Vermont side the range of hills is not high below Ascutney, and notches have been excavated for the passage of William's and Black rivers. Mt. Ascutney is a conical mountain, mostly of eruptive granite, protruded through the calcareous range, and rises to about 3,168 feet above the sea. It is as much isolated in position as it is elevated above the ridge of which it is the culmination.

Perhaps a fourth basin may be said to commence with Ascutney, and terminate in the narrows above Fairlee and Orford.

There is a gap at East Lebanon for the passage of Mascomy river, above which the Mascomy lake basin expands as extensively as the Sunapee lake country at the head of Sugar river. The quartzite range of Moose mountain is broken at the south line of Lyme, and then rises gradually to form Mt. Cuba in Orford, 2,273 feet above the sea. On the west slope of Cuba, Lime and Bass hills, with Sunday and Soapstone mountains, constitute a ridge extending close on to the Connecticut.

On the Vermont side there are no prominent hills adjacent to the river. The valley of White river is the deepest and most extensive yet traversed, as it is the main valley threading north-westerly towards Montpelier and Burlington, and, consequently, the route of the Central Vermont Railroad. Our limits are here much broadened to take in the hilly calcareous country of all the eastern townships of upper Windsor and Orange counties. The proper ridge would extend from Beaver hill in Norwich, and Copperas hill in Strafford, towards Washington, Orange, and the elevated gores of land west of Peacham, into Cabot. Thetford hill is on the subrange next to the river, which is cut entirely through farther north for the outlet of Fairlee pond, and crowds the Connecticut in Sawyer's mountain next the Soapstone hill. Opposite Orford village this makes a precipitous ledge. A view of the closing in of Sawyer's and Soapstone mountains is given in Fig. 20, in which the steep escarpment of the former and the more undulating outline of the latter mountain on the right hand side may be distinctly discerned. In the foreground are alluvial terraces, the view being that seen from Bissell's hill, a little north of Orford village.

The Haverhill section of the valley next commands attention. The

valley widens so as to give a great breadth of alluvial meadow between the villages of Haverhill and Newbury, more so than at any other point in the valley, the nearest approach to it below being in Walpole and Westminster. These meadows are two miles in width, and the river is very crooked, flowing nearly twice as far as the linear distance from Howard's island to the south line of Haverhill. From the village of Newbury, which is located upon a beautiful terrace, one can see the hills rise higher and higher back of Haverhill, to the lofty ridge of Moosilauke, the south-west extension of the White Mountains. There are five peaks in a line below the highest ridge, which are distinguished by their baldness, and known as Owl's Head, Blueberry, Hog's Back, Sugar Loaf, and Black mountains.

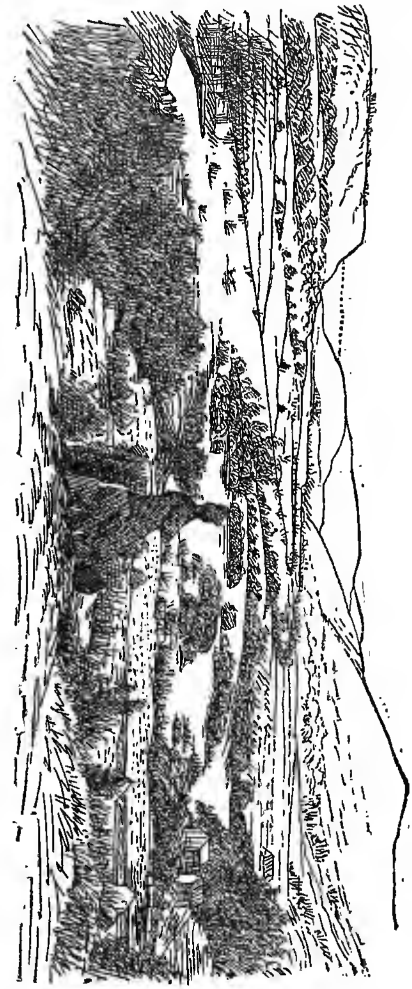


Fig. 20.—GAP BETWEEN SAWYER'S MOUNTAIN AND SOAPSTONE HILL.
From Bissell hill, Orford.

On the Vermont side the hills are scattered, abundant, and are in no way remarkable directly opposite the Haverhill section; but the range from Knox mountain in Orange to Cow hill in Peacham is the counterpart of the Moosilauke group, a little farther north.

The Ammonoosuc section may embrace all that lies east of the Connecticut as far north as Dalton above Haverhill. The calcareous rocks mostly disappear to make way for the older and harder green schist, which gives a different shape to the hills. This is where the Connecticut bends north-east and east, and in the angle of the bend is the Gardner mountain range, reaching nearly 2,000 feet. Landaff, Lisbon, and Little-

ton give slaty eminences in Pond, Pine, Sugar, Eustis, and portions of Mann's hills. The gneissic eminences are Bronson and Ore hills, Green mountain, Iron Ore hill, and Moody ledge in Landaff, and numerous unnamed summits in the western part of Bethlehem.

The Connecticut has excavated a passage through the Gardner mountain range, in what is known as Fifteen-miles falls, from Barnet to South Lancaster, where the water descends nearly four hundred feet. The valley is narrow, rocky, and mostly devoid of superficial deposits above the drift. In contrast with this is the valley of the Ammonoosuc, between Woodsville and Bethlehem, which is full of deposits of modified drift. These differences have given rise to the inquiry whether the Connecticut may not have flowed formerly through the Ammonoosuc valley, passing over the water-shed at Whitefield.

The Passumpsic section is located in a fertile calcareous region, and abounds in deposits of sand, gravel, and clay. It lies entirely in Vermont. On the east are the slate hills of Kirby and Waterford, which are prolonged into the schist eminences of Lunenburg, Victory, and Granby; and there are gneissic and granitic mountains, in the same connection, following around by Willoughby lake to Barton. The notch between Mts. Horr and Pisgah, in Westmore, is the most conspicuous feature in the landscape of all northern Vermont; and the closer it is approached the more irregular it appears. These two hills rise precipitously 1,800 feet above Willoughby lake, having only the water between them, and are less than a mile apart near the upper end of the lake.

The country rises from Crystal lake, in Barton, to Sheffield; and the water-shed between the Passumpsic and Lamoille rivers, through Sheffield, Wheelock, and Walden, coincides with the western border of the Connecticut district. It is nearly all susceptible of cultivation, though abounding in forests; and the rocks are nearly all calcareous.

II. *Coös and Essex District.* This lies at the extreme north of the area of our explorations. It is all mountainous, sparsely settled, largely covered with forests, yet containing many tracts of great fertility. It is the most diversified of all the topographical districts. The main water-shed of New Hampshire passes through the middle portion from Randolph to Mt. Carmel; and, in Essex county, there is a similar ridge from Lunenburg to the state line. The Grand Trunk Railway passes through the

lowest line of depression that can be found in this area. Commencing at the boundary of Quebec and Vermont, with 1,232 feet elevation above the sea, it rises to 1,357 feet at Norton, and thence descends to Connecticut river at North Stratford, which is 915 feet. Following the river down to Groveton, there may be a fall of twenty feet. The road proceeds up the Upper Ammonoosuc, attaining 1,080 feet at Milan water-station. Thence it descends to the Androscoggin valley, passing into Maine with an altitude of 713 feet.

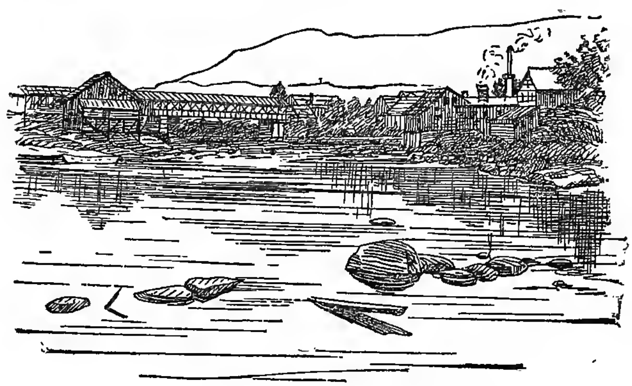


Fig. 21.—MT. LYON, FROM GUILDHALL FALLS.

At the entrance to the Upper Ammonoosuc valley there stands a bold ridge, known formerly as Cape Horn, in Northumberland. Mr. Huntington has proposed to designate it as *Mt. Lyon*, in honor of J. E. Lyon, president of the Boston, Concord & Montreal Railroad. The ridge is too precipitous to be cultivated. A sketch of it is given in Fig. 21.

There are two prominent lines of depression, running in a north-easterly direction, in the Coös region. The first follows the Androscoggin, from Shelburne to Umbagog lake, 713 to 1,256 feet; the second follows the Connecticut river, from 830 feet at Dalton to 1,619 feet at Connecticut lake, and thence to 2,146 feet at the gap above the source of the Connecticut. All the rest of this district is more elevated than these three lines of depression.

Both the elevation and the high latitude of this district render the climate of this district, including the White Mountains, the most rigorous of any in the state. Plants that suffer from protracted winters cannot therefore be successfully cultivated here. Nothing is done with the vine,

and scarcely anything with fruit trees. The staple crops are grain, oats, and potatoes, no county in the United States yielding better results for the latter article than this. On this account there are many manufactories of potato starch here.

As the topography of this district is of special geological interest, a whole chapter will be devoted to it, prepared by Mr. Huntington.

III. *White Mountain Area.* The White Mountains of New Hampshire cover an area of 1,270 square miles, bounded by the state line on the east, the Androscoggin river and the Grand Trunk Railway on the north-east and north, the Connecticut river valley, or an irregular line from Northumberland to Warren, on the west, the less elevated region of Baker's river on the south-west, the Pemigewasset river and the lake district on the south. The Pemigewasset valley makes a prominent notch in it in Thornton and Woodstock. The Saco river cuts the White Mountains into nearly equal parts ;—and it may be convenient sometimes to speak of what lies on the east and the west sides of this stream.

The mountains may be grouped in ten sub-divisions. 1. Mt. Starr King group. 2. Mt. Carter group. 3. Mt. Washington range, with a Jackson branch. 4. Cherry Mountain district. 5. Mt. Willey range. 6. Mts. Carrigain and Osceola group. 7. Mt. Passaconnaway range. 8. Mts. Twin and Lafayette group. 9. Mts. Moosilauke and Profile division. 10. Mt. Pequawket area. Divisions 2 and 3 may be termed "Waumbek" for convenience, and divisions 5, 6, and 8 may receive the name of "Pemigewasset."

Considered as a whole, the main range would commence with Pine mountain in Gorham, follow the Mt. Washington ridge, cross the Saco below Mt. Webster, and continue south-westerly by Nancy mountain, Mt. Carrigain, Mt. Osceola, and terminate in Welch mountain in Waterville. Another considerable range may be said to commence with the Sugar Loaves in Carroll and Bethlehem, and continue westerly by the Twin mountains, Lafayette, Profile, Kinsman, and Moosilauke. A third of some consequence might embrace the Carter range, with Iron mountain in Bartlett. These mountain groups differ much in geological character, age, and marked topographical features.

1. *Mt. Starr King Group.* This has not been explored very extensively, and it is not so much frequented by visitors as most of the other


CRYSTAL CASCADE

districts. It is embraced in the remote portions of the towns of Gorham, Randolph, Jefferson, Lancaster, Stark, Milan, Berlin, and the whole of Kilkenny. It may be bounded by the Upper Ammonoosuc and Androscoggin rivers on the north and east, by Moose and Israel's rivers on the south, and the Connecticut slope on the west. From the extreme outlying foot hill on the west line of Stark to Gorham, the longest diameter of this group, the distance is sixteen miles. The greatest width is thirteen miles, or from Jefferson hill to Milan water-station. The shape of the area, as mapped, is oval-elliptical, being more pointed at the north than the south. The area may comprise 150 square miles.

The Upper Ammonoosuc river flows in a broad valley in Randolph and Berlin, and thereby divides the group into two parts. The source, called the Pond of Safety, is nearly 900 feet above Milan water-station, and there is a depression in the ridge in the south towards Jefferson. For geological reasons, we understand that the northern portion of the Starr King region was once an immense plateau, and the numerous valleys in it now are the result of atmospheric erosion. Not less than seven streams have notched in the edge of this plateau,—the three most prominent erosions being from Berlin, Stark (Mill brook), and Lancaster. There is a central ridge through Kilkenny, the Pilot mountain range, connected by a valley with Mt. Starr King in Jefferson. A branch diverges from this range to Pilot mountain in Stark, formerly ascended by a foot-path from Lost Nation. Green's ledge and Black mountain are spurs to the east from the Pilot range.

From Mt. Starr King to Berlin Falls there runs an irregularly curved range. It is composed of Pliny, Randolph, and Crescent mountains, and Mt. Forest. Section X passes through the centre of this district from Berlin Falls to Lancaster, from which the reader may learn the irregularities of the surface-profile. Mts. Starr King, Pilot, and Randolph are the culminating points, being 3,800, 3,640, and 3,043 feet respectively. The region is entirely covered by a forest.

2. *Mt. Carter Group.* This lies in Shelburne, Bean's Purchase, Chatham, and Jackson, and is the least known of all the mountain districts. I do not find any explorer of it anxious to continue his investigations therein. The mountains, however, are like all other elevated tracts of land far away from habitations. There seems to be a heavy range from

Gorham to Jackson, quite near the Peabody and Ellis valleys, while on the east the slope towards the Androscoggin is quite gradual. Mt. Moriah is one of the more northern peaks of this chain. Fig. 19, p. 146, will show its features. The view is from a point in the Androscoggin valley in Shelburne. The distance is so great that the stern, rugged features of the mountain are much softened. Wild river occupies a broad valley in Bean's Purchase, trending north-easterly. The highest part of the Carter range lies next the Peabody river; and the western slope is much steeper than the eastern. A view of Mt. Carter, from a point south of the village of Gorham, is quite impressive, as exhibited in the sketch.

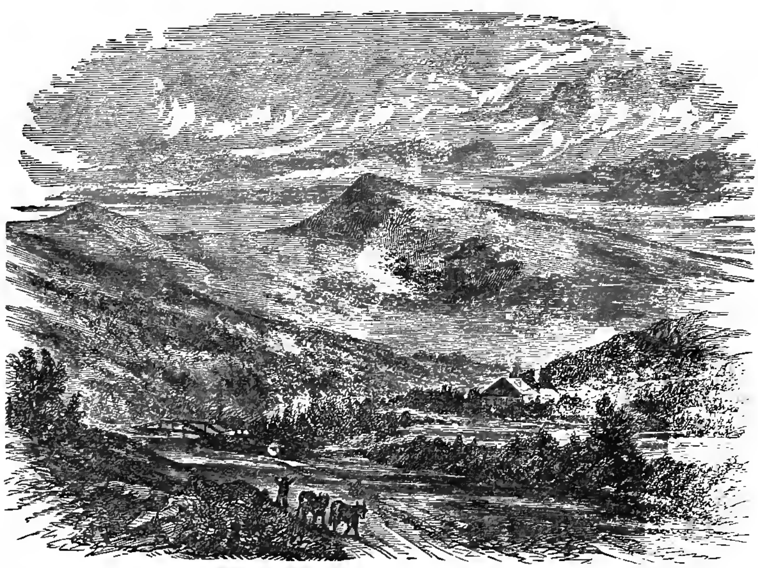


Fig. 22.—MT. CARTER, FROM GORHAM.

Imp mountain lies between Moriah and Carter. There is a very deep notch between Height's and Carter's mountains, in the edge of Jackson. The east branch of Ellis river flows from it south-easterly; and the range courses easterly so as to form the entire westerly and southerly rim of the Wild river basin. Several tributaries flow to Wild river on the north; and others to the Saco on the south of this easterly range. It curves more northerly near the Maine line, terminating, so far as New Hampshire is concerned, in Mt. Royce, directly on the border.

The Carter mountain group sends five spurs into Jackson and Chatham. The first is the continuation of Height's mountain, adjoining the Pinkham road, to Spruce and Eagle mountains, near Jackson village. The second comes down from Carter mountain, to include Black and Tin mountains. The third spur takes in Doublehead mountain, and is bordered easterly by the east branch of the Saco and the Wildcat branch. Near the line of Bean's Purchase and Chatham lies Baldface mountain, 3,600 feet high, from which run the fourth and fifth spurs. The fourth comprises Sable mountain, in Jackson, and its foot hills. The fifth is composed of Mts. Eastman and Slope, in Chatham, which run into the Pequawket area.

3. *Mt. Washington Range.* The main range of Mt. Washington extends from Gorham to Bartlett, about twenty-two miles. The culminating point is central, with a deep gulf towards Gorham, a slope on the north, formed partially by the westerly Mt. Deception range, which also produces the broad Ammonoosuc valley on the west, in connection with the axial line of summits. On the south there are two principal valleys, the more westerly occupying the depression of Dry or Mt. Washington river, and the easterly passing down the slope of Rocky branch, which travels easterly near its termination, so as to be parallel with the Saco in Bartlett. Starting with the Androscoggin valley, the range commences in the low Pine mountain. In the south-east corner of Gorham this is intersected by the pass of the Pinkham road between Randolph and the Glen house. Next, the land rises rapidly to the top of Mt. Madison, 5,400 feet. The range now curves westerly, passing over the summits of Adams, Jefferson, and Clay. The gap between Clay and Washington is the best place to behold the deep abyss in which the west branch of Peabody river takes its rise. From Washington, one can easily discern the east rim of the Great Gulf, for upon it is located the carriage-road to the Glen house. From the Lake of the Clouds, and the eminence south of Tuckerman's ravine to Madison, it is easy to imagine the area an elevated plateau,—of which Bigelow's lawn is a portion,—out of which Washington may rise 800 feet. On the east of Washington, two deep ravines have been excavated,—Tuckerman's and Huntington's. The first runs easterly, and holds the head waters of Ellis river; the second commences at the southernmost angle of the carriage-road, at the fifth mile

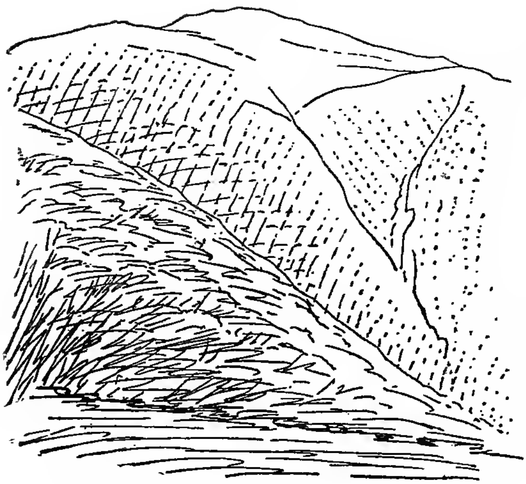


Fig. 23.—MT. JEFFERSON AND GREAT GULF.
From Half-way house.

post, and runs towards the first. The frontispiece will show the character of these two valleys, and their relations to the adjoining mountains.

The shape of Jefferson and the foot of Adams, as seen from the Half-way house, are indicated in Fig. 23. The sketch is designed to show the shape of the Great Gulf. Instead of regarding the eminences as gravel banks, the reader must realize that they represent 2,000 feet of altitude above the station of the observer.

Fig. 24 sketches the east side of Mt. Washington, from Thompson's falls, in the Carter range, south of the Glen house.

Fig. 24.—RAVINES ON MT. WASHINGTON, FROM THOMPSON'S FALLS.

The deep valley on the left is Tuckerman's ravine. Huntington's ravine, the head of Peabody river, lies back of a low, woody ridge terminating

just behind the prominent spruce tree in the centre of the foreground. The tops of the ridge back of Huntington's ravine, and the one to the extreme left, mark the edge of the 5,000 feet plateau about Mt. Washington. Mt. Washington itself rises above the plateau a little to the right of the centre of the sketch. The projection between the two ravines is known as Davis's Spur.

These and other topographical features of the Mt. Washington range are well represented upon a map designed to illustrate the Alpine and sub-Alpine districts of Waumbek, which will appear in the chapter upon the distribution of insects in New Hampshire.

Past Mt. Washington the main range descends to the pass of the Lake of the Clouds,—the source of the Ammonoosuc river,—5,000 feet high. The first mountain is Monroe—a double, ragged peak scarcely ever visited, the road passing around it. Next follow in order Mts. Franklin, Pleasant, Clinton, Jackson, and Webster. The gaps between all these are small. Mt. Pleasant may be recognized by its dome shape. Fig. 25 will give a good idea of the ranges as seen from near the White Mountain house in Carroll. The last peak on the right is a fragment of Jackson. It lies a little back from the line; and the road to Crawford's lies in front of it.

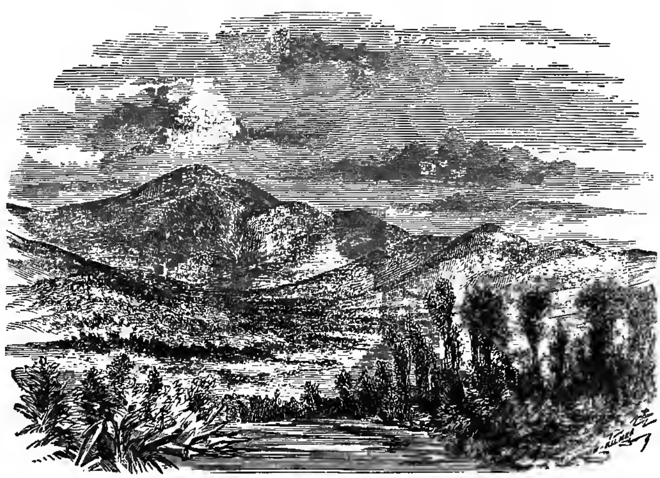


Fig. 25.—MT. WASHINGTON, FROM NEAR FABYAN'S.

The valley in front is the broad basin of the Ammonoosuc; and the lower slopes of the Deception range on the left. Mt. Webster is a long

mountain with precipitous flank on the side towards the Saco. It is directly opposite the Willey house. It is one of the main features of the notch.

The east flank of the mountains, from Monroe to Webster, is washed by the powerful Mt. Washington river, which forms the central line of Cutts's grant, heading in Oakes's gulf. It is the proper continuation of the Saco valley, its source being several miles farther away than the small pond near Crawford's. In dry seasons the water may be low, which fact, in connection with a broad, gravelly expanse of decomposed granite near the lower end of the valley, gave rise to the early appellation of "Dry river." Dr. Bemis proposed that it receive the name of Mt. Washington river.

From the east side of Oakes's gulf, or the continuation of Bigelow's lawn, two ranges course southerly. The western follows the Saco to just opposite Sawyer's rock, having, in the lower part of its course, Giant's stairs, Mt. Resolution, Mt. Crawford, Mt. Hope, and "Hart's ledge," of

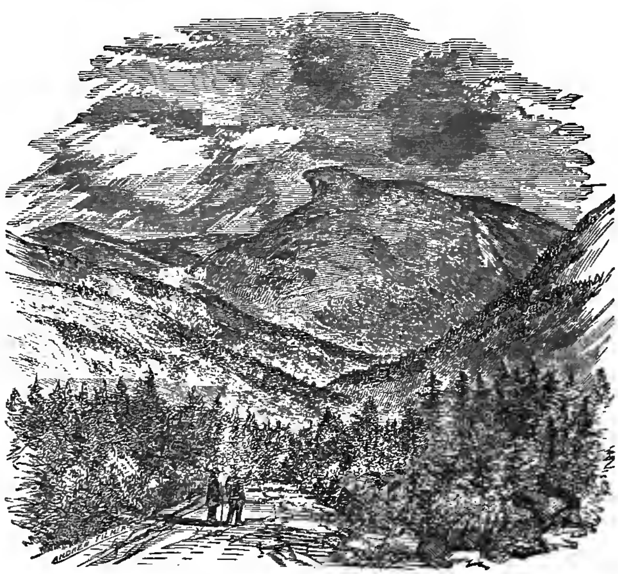


Fig. 26.—MT. CRAWFORD, FROM THE NORTH-WEST.

Boardman's map. Two heliotypes show the shape of Crawford. When seen from the north-west, a little below the Willey house, the summit

projects northwardly, like the head of a wild beast, overhanging the granitic slope. From near Dr. Bemis's residence, one gets the idea of a broad, conical peak, furrowed by a temporary stream. There have been avalanches down the west side, where very large rocks have bounded into the middle of the Saco flood plain, 175 feet at a single leap. The overhanging character of Mt. Crawford may be somewhat exaggerated in the figure; but any one's pencil is tempted to distort somewhat the characteristic features of summits, in order to give strangers the proper impression of their effect in the landscape.

The more easterly range is elevated but is not conspicuous, and consequently is not named. It is flanked by Rocky Branch on the west and by Ellis river on the east. Near Jackson village it curves easterly, and terminates in the granitic Iron mountain. Between Sawyer's rock and the mouth of Rocky Branch there is a range running easterly, with a spur towards Mt. Crawford, separated by Razor brook from the Mt. Hope ridge. It lies between the southern termini of the two divergent ranges pointing southerly from Bigelow's lawn. Its precipitous character is shown in the sketch placed at the end of Chapter I.

4. *Cherry Mountain District.* The Mt. Deception range consists of four peaks,—Mt. Mitten, Mt. Dartmouth, Mt. Deception, and Cherry mountain, formerly called Pondicherry. It is separated by a considerable valley from Mt. Jefferson, and its gentler slope lies on the northern flank

Fig. 27.—CHERRY MOUNTAIN, FROM TWIN MOUNTAIN HOUSE.

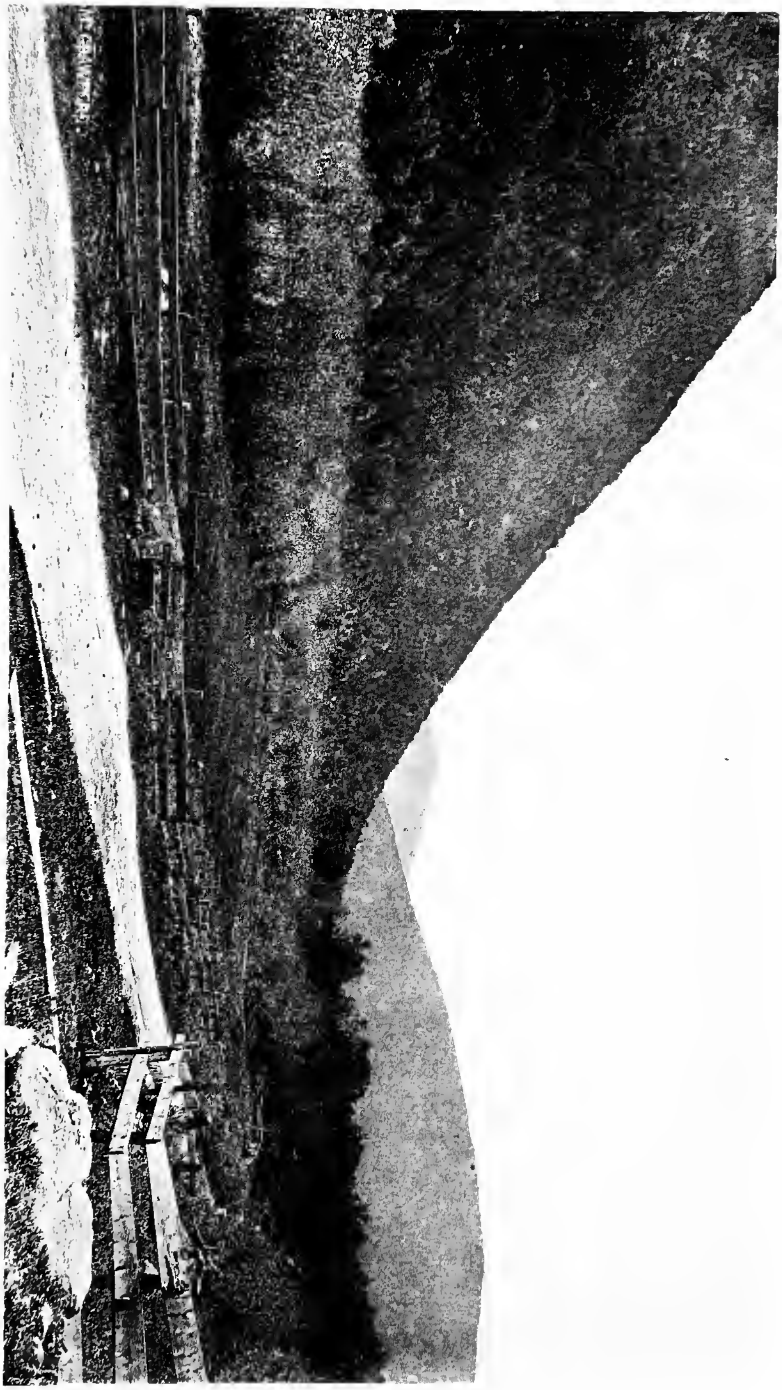
towards Israel's river. The road from Fabyan's to Jefferson passes between Cherry and Deception. The range runs nearly at right angles

to the main mountain axis. Cherry mountain has a northerly spur of large dimensions, called Owl's Head. A view of Cherry mountain, as seen from a point half a mile west of the Twin Mountain house, is presented in Fig. 27. The northern part of the range seems to be the highest.

5. *Mt. Willey Range.* This starts from near the White Mountain house in Carroll, and terminates in Mt. Willey. Its northern terminus is low, and the highest peak is at the southern end of the range. Six granitic summits may be counted before reaching the high summit of Mt. Tom, just behind the Crawford house. This peak is high and imposing, as seen from the vicinity of the Crawford house. The stream forming Beecher's cascade passes between Tom and the next summit south.

This latter peak has been named Mt. Lincoln, in honor of the late President Abraham Lincoln, by some unknown person. This title has been applied to stereoscopic views of it: but if we apply to the naming of mountains the canons of nomenclature required for scientific terms, it will be impossible to retain the name of Lincoln, because it has been preoccupied at Franconia. It is doubtful whether Mr. Fifield proposed to call the nameless peak Lincoln in advance of photographic usage at Crawford's; but the fact of its prior publication in a map is sufficient reason for adopting the name in Franconia, and hence to reject the appellation in the other case. I propose, therefore, the name of *Mt. Field* for the eminence near the Crawford house, in honor of the worthy gentleman (Darby Field) who first ascended Mt. Washington in 1642, and will use it upon the map and in the descriptions of this report. See p. 44.

From Mt. Field to Mt. Willey the high land is continuous, reaching an elevation of 4,300 feet. It then drops off abruptly, and terminates, while the water-shed continues into the Carrigain district. Ethan's pond is situated a little to the south-west of the base of the precipice. This is the extreme head of the waters flowing into Merrimack river. The Field-Willey range is directly opposite to Mt. Webster; and the intervening valley is the most striking part of the White Mountain notch. The head of the notch is formed by Mt. Willard, only about 550 feet above the Crawford plain. It is covered by trees on the north side; and the south is precipitous, looking down the valley of the Saco. One of our heliotypes shows this view, which is one of great beauty.



6. *Carrigain and Osceola Group.* Across from Mt. Webster the Mt. Washington range is continued in the mountains culminating in Carrigain, 4,678 feet high. This is a lofty, conical summit, occupying the most conspicuous position in the horizon when seen from Mts. Washington, Crawford, Pequawket, Moosilauke, and Lafayette. Two summits in this line, north of Carrigain, have names, viz., Mts. Nancy and Lowell,—the latter after Abner Lowell, of Portland, and known heretofore as Brick-house mountain. There is an interesting gap between Lowell and Carrigain, represented in the chapter on Scenery. The original of this sketch was prepared by George F. Morse, of Portland, who visited Mt. Carrigain, in company with G. L. Vose, in 1869. The depth and impressiveness of the notch remind one of the great gap between Willey and Webster. It would be a good route for a carriage-road from Bartlett over to the east branch of the Pemigewasset. Nearly west from Carrigain is Mt. Hancock (Pemigewasset of Guyot). It is nearly as high as Carrigain (4,420 feet), and falls off gradually to the forks of the East Branch on the east line of Lincoln. The space between Carrigain and Osceola abounds in granite mountains, often with precipitous sides. Tripyramid may represent a spur (if not an isolated group) from them, running towards Whiteface. Between Tripyramid and Osceola there is a deep gap, in which the Greeley ponds are situated. Osceola, or "Mad River peak" of Guyot, is a double mountain with a deep excavation on the south side for one of the tributary streams of Mad river. The range is continuous into Tecumseh, Fisher's, and Welch mountains in Waterville. Sketches of Osceola and Tecumseh are presented herewith.

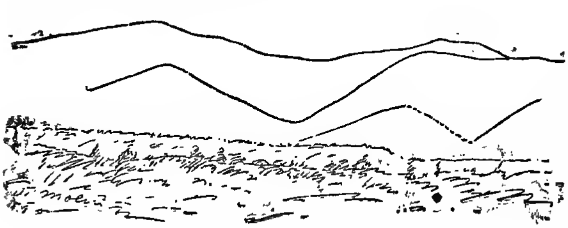


Fig. 28.—MT. OSCEOLA.

From S. M. near Greeley's hotel, Waterville.

Osceola is the highest mountain on the left, in Fig. 28, and the most distant peak on the right is its eastern spur. Mad river comes from a valley to the right of all the hills represented in the sketch. There is a deep valley to the south-west of Osceola. Then a mountain appears much like Osceola reversed. It is shown in Fig. 29,

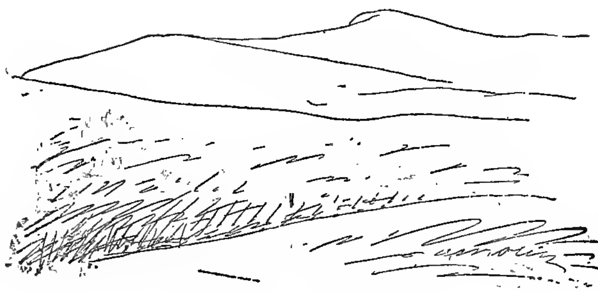


Fig. 29.—MT. TECUMSEH.
From S. M. near Greeley's hotel.

with the name of Mt. Tecumseh, proposed, as I understand, by E. J. Young, photographer, of Campton village, who has published at least two stereoscopic views of it, with this name appended.

Cone mountain succeeds Welch, but this is not so conspicuous an eminence as appears upon some of the maps. North-westerly from Osceola the high granitic range continues as far as the East Branch, the last summits being Black and Loon Pond mountains. This very interesting region is unknown to most tourists. The only mountain accessible by a path is Osceola, from which most of the others can be seen to advantage.

7. *Passaconnaway Range.* This has an easterly course, and bounds the White Mountain area upon the south. The most massive of the series is Black mountain, or "Sandwich Dome" of Guyot, on the line between Sandwich and Waterville, over 4,000 feet high. The annexed sketch shows this mountain behind Noon Peak, or the one terminating abruptly in the centre of the view. The peak to the right is Denison's. The observer is supposed to be stationed near Greeley's hotel. A path leads to this summit, where one can see advantageously the Waterville basin as flanked by Tripyramid and the Osceola range. A high plateau extends from Black to Tripyramid and Whiteface. The latter is double, and the southern part has been recently occupied by the U. S. Coast Survey as a signal station. From here Passaconnaway looms up majestically. It is a sharp dome, covered by trees to the very summit, and rises far above the surrounding

Fig. 30.—BLACK MOUNTAIN AND NOON PEAK.
Greeley's hotel in the foreground.

peaks. Our most recent calculations place this summit in the east edge of Waterville. Passaconnaway lies a little north of the main ridge. The space between this and Chocorua is occupied by low, ragged mountains.

Chocorua is the sharpest of all the New Hampshire summits, and can be the most easily recognized and located on this account. One of the heliotypes gives a distant view, and the annexed figure illustrates the appearance of the peak near at hand. The cone is composed of an

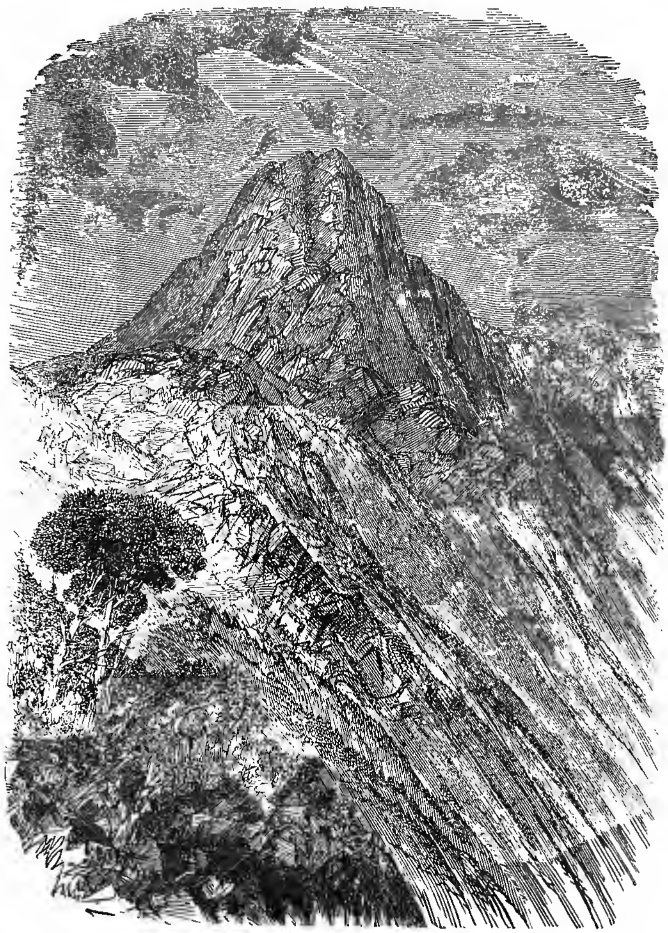


Fig. 31.—SUMMIT OF CHOCORUA.

uncommon variety of granite. To the eastward the mountains gradually fall off till the plains of Conway are reached. The country south of this mountain range is low and undulating.

Albany Mountains. Swift river divides the Albany mountains into two parts, rising on the long easterly slopes of the Carrigain-Osceola range and Green's cliff. Those just described form the southern rim of this basin. Those upon the north side are the Mote mountains, adjacent to Conway, and mostly unnamed peaks along the south bank of the Saco in Bartlett, joining on to Tremont in a wild tract of forest. The Mote mountains have been burnt over, so that they appear unusually barren when seen from a distance. They are the newest of the White Mountains, while the foundations of the Passaconnaway range are the oldest. With a different arrangement of description, the *Albany basin* may be said to have very gentle slopes upon the inside, but on the Saco valley range and the Chocorua group the hills dip abruptly in opposite directions. This basin may also be termed a projection eastwardly from the Carrigain range.

8. *Mts. Lafayette and Twin.* This area is bounded on the north by the Ammonoosuc, on the east by New Zealand river and the east branch of the Pemigewasset,—which curves so as to make it the south line, also,—on the west by the north branch of the Pemigewasset. It contains two prominent ranges,—first, the western one, from Haystack to the junction of the two branch streams; and the other, from the Twin mountains to the mouth of the Franconia branch. The Haystack, a conical peak, is separated by a series of small gaps from Lafayette. The Lafayette mountains are peculiar in form. The range is quite elevated, extremely narrow, and consisting of seven summits. Lafayette, 5,290 feet, is the second from the north. Then follow Mt. Lincoln of Fifield, 5,101 feet, two nameless peaks, Mts. Liberty and Flume, each 4,500 feet, the latter to the south-east of the usual course of the ridge. This elevated ridge is composed of dark felsite. The peaks south of Mt. Flume are coarsely granitic, being Big and Little Coolidge, Potash mountain, and others.

The Twin mountain range occupies the middle line between the Saco and Pemigewasset rivers. The two most prominent peaks are a mile apart, eight miles south of the Twin Mountain house, and are 5,000 feet high. Scarcely any mountains are more difficult to reach than these, on account of the stunted growth near their tops. The ridge is broad, and keeps at almost the same level for two or three miles south of the summit. On the west of this range there is an isolated ridge of no great dimen-

sions; and, on the north-east, a mass of mountains has been separated from the main summits by the erosive action of Little river. The highest of these separated peaks is sometimes confounded with the Twin mountains, because only one of the Twins is seen from the hotel named after them. The double character is seen from either Washington or Lafayette, and not from the Twin Mountain house. That the early distinctions may not be forgotten, and for the sake of fixing the position of a noble mountain, I venture to name the highest of the unnamed peaks north-east of Little river *Mt. Hale*, after Rev. E. E. Hale, of Boston, editor of *Old and New*, who assisted Dr. Jackson in exploring the White Mountains, and has done much to make them famous by his writings.

To the north of Mt. Hale are three granitic lumps, which, for convenience, I have called the Three Sugar Loaves. On the north-east side of Twin mountain is a curious nubble or small conical summit 150 feet high, which is observable from several places along the Ammonoosuc valley. It is probably an enormous vein of very coarse granite. Fig. 32 is a rough pen sketch of the outlines of the mountains between Haystack and the first Sugar Loaf, as seen from near the Twin Mountain house. Their names are very plainly indicated, and those interested will readily recognize the place of the newly named peak. A sketch of the outlines of the mountains to the south, as seen from the north Twin mountain, is given in Fig. 33. This is a view very rarely seen; but the proprietors of the Twin Mountain house would add much to the attractiveness of their establishment if they would construct a bridle-path to the top of the mountain.

A view of the Twin mountains and Haystack, from the east part of Bethlehem hill, Fig. 34, will show better than words the several ridges and valleys composing the range. They show well, also, from the Wing Road station, and from Sugar Hill, Lisbon, as represented in Fig. 35.

There is a deep and broad valley between the Mt. Tom and the Twin ranges. The divide between the New Zealand waters flowing to the north, and of the East Branch rivulets descending southerly, is quite low. It has all been excavated by atmospheric agencies;—since, from geological reasons, it is clear that Mts. Twin and Tom were once continuous.

9. *Moosilauke and Profile.* A narrow gap, 2,000 feet above the ocean,

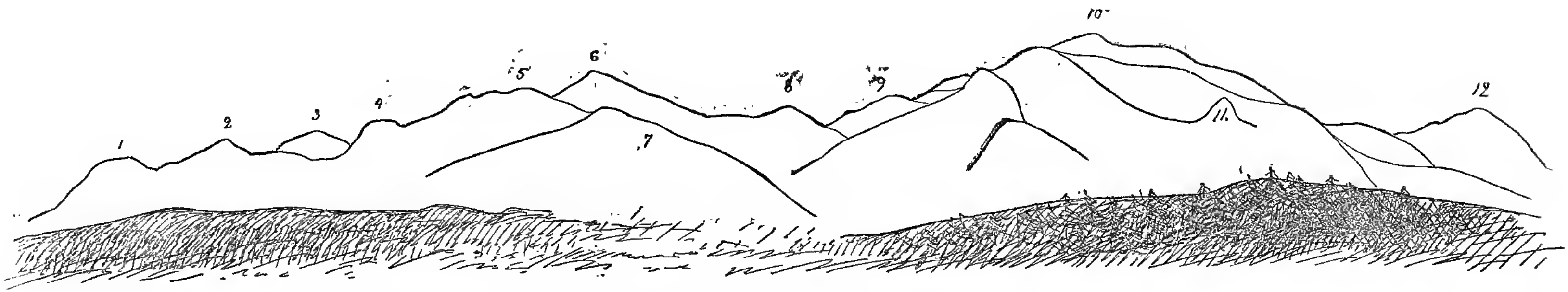


Fig. 32.—PROFILE OF MOUNTAINS BETWEEN HAYSTACK AND THE FIRST SUGAR LOAF.

EXPLANATION.—1. First Sugar Loaf. 2. Second Sugar Loaf. 3. Mt. Tom. 4. Third Sugar Loaf. 5. Unnamed peak. 6. Mt. Hale. 7. Low ridge between Ammonoosuc and Little rivers. 8, 9. Little River mountains. 10. North Twin mountain. 11. The Nubble. 12. Haystack.

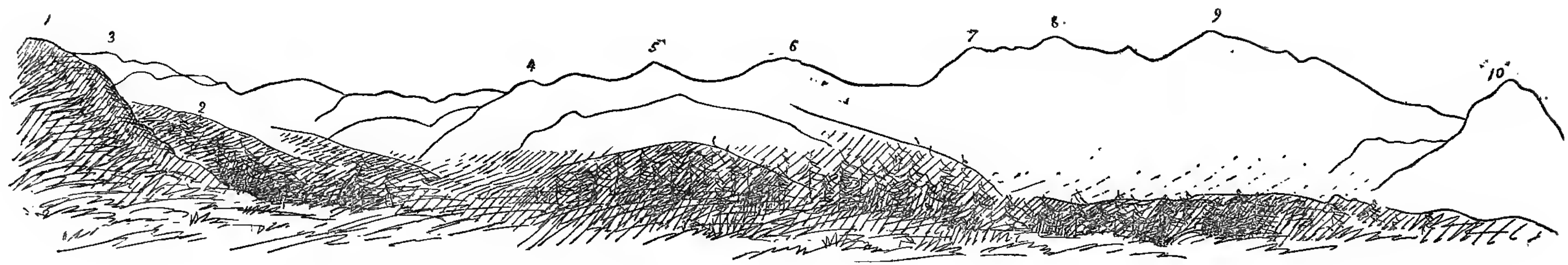


Fig. 33.—PROFILE OF MOUNTAINS BETWEEN SOUTH TWIN AND HAYSTACK, AS SEEN FROM NORTH TWIN.

1. South Twin. 2. Spur of South Twin, very near the point of observation. 3. Mt. Osceola. 4. Coolidge mountain. 5. Mt. Flume. 6. Mt. Liberty. 7. South end of Lafayette range. 8. Mt. Lincoln. 9. Mt. Lafayette. 10. Haystack.

separates the Lafayette from the Profile range at the site of the famed

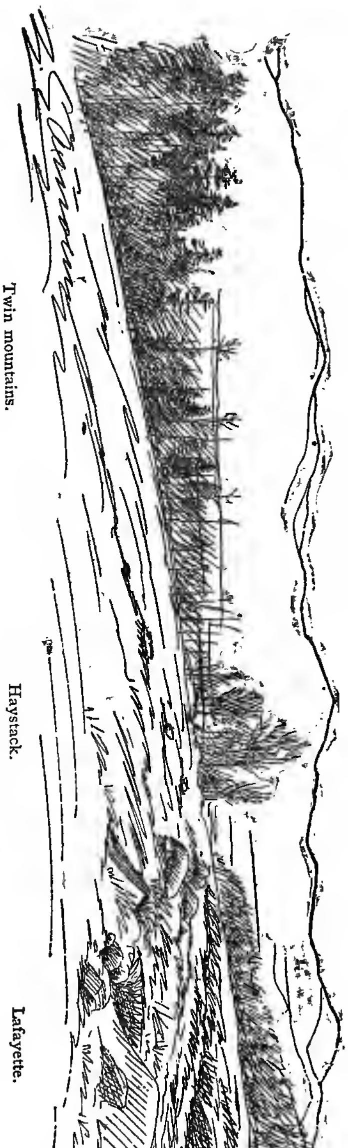


Fig. 34.—MOUNTAIN RANGE FROM LAFAYETTE TO TWIN.

Fig. 35.—FRANCONIA MOUNTAINS, FROM SUGAR HILL, LISBON.

"Old Man of the Mountains." On the north is Eagle cliff, too precip-

itous to be scaled; while the Profile or Cannon mountain on the south-west is nearly as steep, and it is absolutely perpendicular a mile southerly. One of our heliotypes represents this valley, closed, apparently, by Eagle cliff.

The north end of the range consists of a pile of granite hummocks, attaining the height of 3,850 feet. A terribly rough valley separates it from the long range of Mt. Kinsman, which extends to the extreme south-east corner of Landaff. It is ascended from the village of Landaff, and the trip is easily made. The relations between the Profile and Lafayette range may be seen in a view of them from Thornton. Lafay-

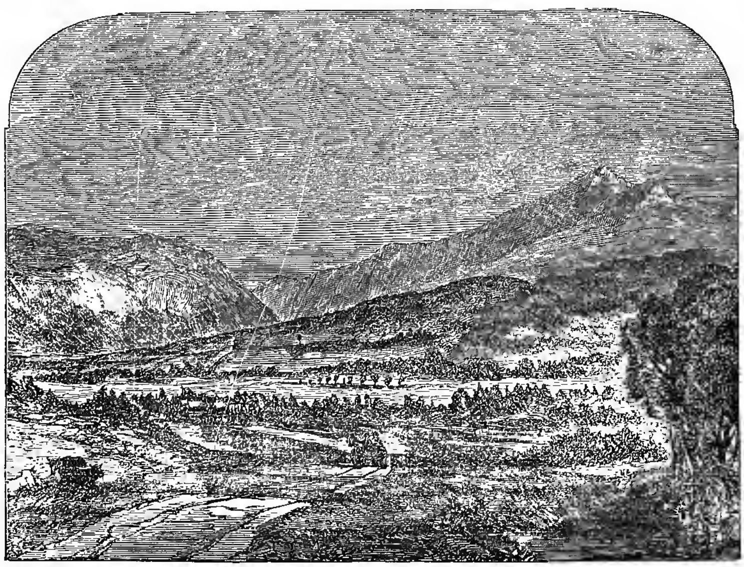


Fig. 36.—FRANCONIA MOUNTAINS, FROM THORNTON.

ette is the highest peak on the right, and Mt. Flume appears a little lower down. The deep valley of the Pemigewasset lies in the centre, and Profile on the left. The precipitous character of Profile does not show advantageously. Only the lower summit of this mountain is generally visited, the apex being still covered by trees.

Moosilauke is the most south-westerly spur of the White Mountains. The summit is in the eastern part of Benton; but Woodstock and Warren

own parts of its expanse. The water-shed continues from it into Carr's mountain in Warren and Wentworth; but the saddle between them is a low one over which a road to the Pemigewasset valley has been contemplated. Two ranges of foot hills border Moosilauke on the west,—first, the familiar name of "Black mountain;" second, five peaks, called respectively,—proceeding northerly from the railroad,—Owl's Head, Blueberry, Hog's Back, Sugar Loaf, and Black mountains.* The map shows a long range, called Blue ridge, on the east flank of Moosilauke in Woodstock. The name of Moosilauke is said to signify a bald place. This is one of the finest of the White Mountains to visit for scenery, and it is easily ascended over the recently constructed turnpike road.

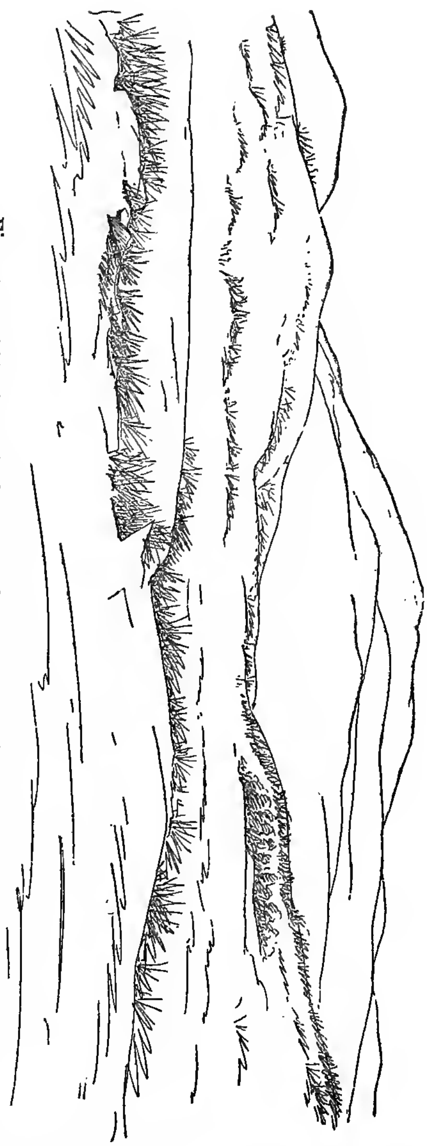


Fig. 37.—MOOSILAUKE, FROM HILL SOUTH OF VILLAGE OF WARREN.

10. *Pequawket.* This is the smallest of all the areas described. The predominant mountain is conical in shape, 3,300 feet above the sea. A house upon the summit can be seen from every point of the compass. On the north this peak passes into the north-easterly spur coming down from the Carter district. On the south a connection is made with the Green hills, which are elevated granitic piles in the east part of Conway.

* This makes two Black mountains in the same town.

Maps and Profiles. In the atlas accompanying this report will be found a large representation of all these White Mountain districts. The shapes of the several ranges and peaks are given as truthfully as is possible upon the model which served as the basis of the photograph. For

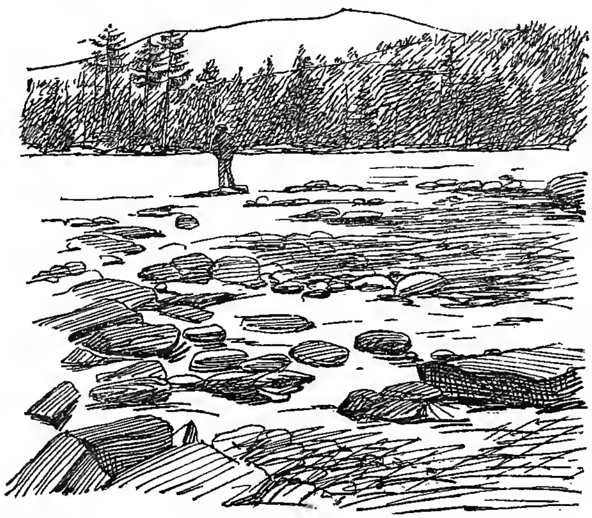


Fig. 38.—MOOSILAUKE, FROM WACHIPAUCHA POND.

more minute information concerning the topography of this region, the reader is referred to this sketch. Many of the features will be referred to in the descriptions of the formations building up the eminences.

The atlas will also show a large number of mountain profiles taken from several points of view. The following have been kindly furnished by Geo. F. Morse, of Portland, Me.: 1. Panorama from Mt. Pequawket. 2. White Mountains, from the "Bill Merrill" hill in Maine. 3. Panorama from Trafton mountain, Cornish, Me. 4. View of the Carter and Baldface mountains in Chatham, Bean's purchase, and vicinity. 5. Profiles, as seen from Mt. Caribou, Me. 6. Same, from Pleasant mountain. 7. Part of a panorama from Mt. Carrigain. We hope to add other panoramic profile views from Mt. Washington, and, possibly, from other prominent peaks. A greater amount of exact topographical information cannot be given, except after elaborate surveys,—such as have never been contemplated by the act authorizing the present explorations.

IV. *Lake District.* This consists largely of the hydrographic basin of Winnipiseogee lake, with sandy plains carrying tributaries of the Saco. It is normally a plain with four isolated mountain masses imposed upon it. These are the Gunstock and Belknap mountains, Red hill, Ossipee mountains east of the lake, and the Green mountain in Effingham. All these mountains are composed of igneous material, which seems to have been poured out over an uneven floor of rocks deposited in the Montalban period.

The Belknap range lies in the towns of Gilford, Gilmanton, and Alton, on the south-west side of Lake Winnipiseogee, covering an area ten by four miles, measured along the greatest diameters. From the point opposite Thompson's island in Gilford the ridge gradually rises to the peak known as Belknap. This is directly connected by a low saddle with the Mt. Gunstock of the Coast Survey, 1,914 feet high. From Mt. Belknap a ridge turns south-easterly, and in the extreme north-east corner of Gilmanton makes a curve, so as to run a few degrees north of east towards the lake. This so-called spur is really the main range, and it continues on to Alton, as an essential prolongation of the south-easterly range from Mt. Belknap. In Alton, Mts. Straight-back, Major, Pine, and Avery hill are developments of this group. To the south of these there is a gap low enough for a road from Gilmanton Iron Works to Alton Bay. Southward the mountainous area terminates in the easterly running hills known as Rocky mountain. The principal part of the region is heavily wooded, save the highest summits, which are practically above trees; and there is uncultivated land enough to make a township as large as Brookline.

Red hill received from Dr. Timothy Dwight the name of Mt. Wentworth, at the beginning of the present century. The mountain area is of elliptical shape, with two summits, the northern* 2,043, and the southern 1,769 feet in height. The length is three miles; the breadth about half as much. It lies chiefly in Moultonborough, and partly in Sandwich. Owing to its proximity to Center Harbor, Red hill is much visited by tourists.

The Ossipee mountains occupy the largest of all these mountainous areas, of oval form, measuring about six by ten miles, and are situated in the adjacent corners of Moultonborough, Ossipee, Tamworth, and Tufton-

* Called western by Guyot.

borough. The broadest portion of the area is in Tamworth and Ossipee. The Bearcamp river washes the northern base of the mountains. Two of its tributaries have excavated north and south valleys out of the north slope, leaving an east and west ridge six miles long. This juts out from near the middle of the main range of about eight miles length, turning somewhat easterly in Moultonborough and Tuftonborough. The two most elevated points, called for convenience North and South Ossipee, lie in the north-south range. Two east flowing streams have excavated very large valleys out of the eastern flank of these granitic piles, the first and largest, known as Lovell's river, discharging into Ossipee pond, and the second, a tributary of Pine river, coming out of Dan Hole pond. At the upper end of Dan Hole pond is a hamlet known as Canaan. There is no road to this place from Moulton mills, up the valley of the outlet, as one would naturally expect, but over the elevated south rim of the valley from Tuftonborough. The height of the loftiest Ossipee mountain is estimated at about 2,000 feet. There are no important streams on the west side of these mountains. The seven brooks which course down the abrupt slope often produce cascades, but have not made notable excavations in the edge of the feldspathic mass.

Green mountain in Effingham is four miles long, shaped much like Red hill, save that the two parts are less deeply notched, and the course is nearly east-west. It is about one fourth larger in every way, vertically as well as horizontally.

Except two ranges, the rest of the Lake district is nearly level. The first lies in Eaton and Madison, including the easterly part of Freedom; the second is a continuation of the Ossipee water-shed through Wolfeborough into Brookfield and Middleton. Also, about Center Harbor and Laconia there are isolated hilly knobs.

The sandy plains of Madison, Freedom, and Ossipee are elevated from 400 to 525 feet, extending to North Conway and Bartlett, in the mountain district. The average is nearly that of Lake Winnipiseogee. The soil is very sandy, much of it being left for the growth of small pines. Between the Ossipee and the Passaconnaway range the average elevation of the land may be from 550 to 600 feet, largely in the towns of Tamworth and Sandwich. In Tamworth, Chatman's, Great, and McDaniel's hills are the highest points. The soil is better, and in favorable

locations, say along the extensive meadows of the Bearcamp river, there are many large and profitable farming establishments. An excellent idea

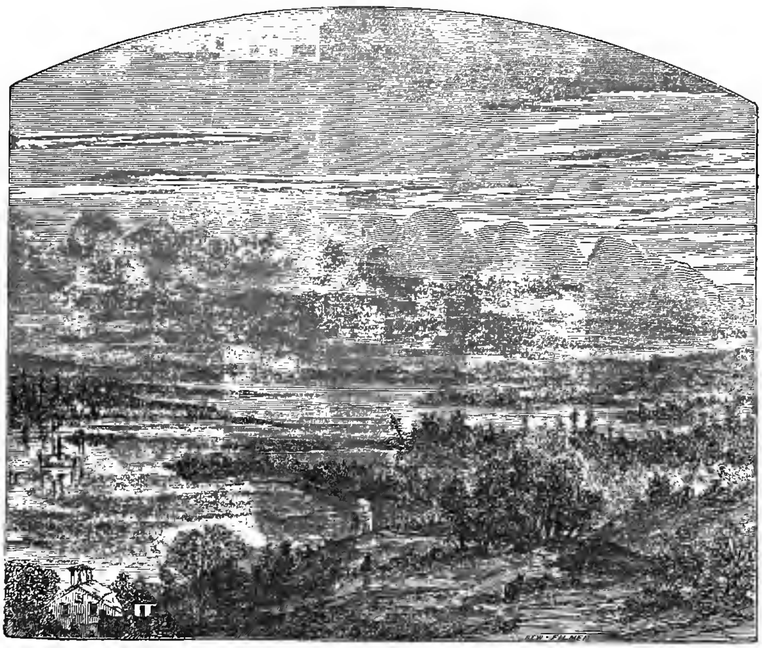


Fig. 39.—LAKE WINNIPISEOGEE, FROM CENTER HARBOR.

of the country about Lake Winnipiseogee may be derived from a view of it given in Fig. 40. The observer looks from the east flank of Sunset hill, back from Center Harbor landing. The highest peak on the extreme right is Mt. Gunstock; the highest on the extreme left is the southern edge of Ossipee; those in the distance on the left bound this district in Alton, New Durham, and Middleton. The borders of the lake are usually of hard pan, sloping gradually to the water's edge. The general course of the basin is S. 25° to 30° E., the islands and points showing essentially the same trend. This direction is determined by the corresponding courses, parallel to each other, of the Gunstock and Ossipee ranges.

V. *The Merrimack Valley District.* This includes more than the hydrographic basin on the west, and less on the north. It is bounded by

the White Mountains on the north, extending as far as Woodstock in the valley; on the north-east by the Lake district, which extends close to the Pemigewasset in Ashland; on the east by the coast slope; slightly on the south-east and entirely on the south by Massachusetts; on the west by the Connecticut valley district, or, more exactly, the eastern boundary of the Coös quartzite. It may well represent the average physical appearance of New Hampshire, consisting of numerous hills and mountains, mostly cultivable, interspersed with sandy plains, alluvial flats, and entirely underlaid by gneissic or granitic rocks. It is much the largest of the topographical districts. There are only two marked topographical divisions of this tract,—the double mountainous range along the western borders, and the Merrimack valley.

The more western of the two ranges along the western border has been referred to in the description of the first district. More particularly, it may be said to follow the line of division between the two districts. It commences in the east part of Piermont as Iron and Piermont mountains. It is the Cuba mountain range in Orford, Smart's mountain in Lyme, Moose mountain in Hanover, Grantham and Croydon mountains between Plainfield and Newport, Perry's mountain between Charlestown and Unity. It is wanting in much of Charlestown, Langdon, and the neighborhood of Bellows Falls. Between Walpole and Hinsdale there is a series of hills, mostly unnamed, which mark the line, though some of them are covered by slate.

From Warren to Plymouth, Baker's river has cut through the range transversely. Webster Slide and Mist mountains are continuous with Iron mountain. The valley between the two ranges commences east of Piermont mountain, bordered easterly by Ore hill, Warren, the water flowing northerly. In the same depression Pond brook rises, flowing to the south-east to join Baker's river. Other tributaries flow in the same direction in Wentworth. The depression is again markedly manifest in Dorchester, having Smart's mountain range on the west, and the Groton hills on the east. It is more pronounced still in Canaan, Enfield, and the east part of Hanover. The quartz range is broken first in Lyme, and more markedly by the outlet of Mascomy lake in East Lebanon. The lowland water-shed between the Mascomy and Sugar rivers lies in the swampy district near the south line of Enfield. The Croydon range

borders the valley to Claremont, where the erosion is more observable than at East Lebanon, allowing Sugar river to pass into Claremont. This river is further remarkable, since it cuts the main range, also draining a large area east of Sunapee, which would more naturally flow into the Merrimack.

From Newport the valley between the parallel ranges passes more easterly into Goshen and Lempster, rising in the swamps near Dodge pond, the source of the tributaries of Cold river, which courses southerly through Acworth, Langdon, and the corners of Alstead and Walpole. North Unity and North Acworth possess water-sheds parallel to each other and running easterly, having Little Sugar river between them. There are no notable hills on either side, though the land is high. This irregularity is induced by the rising up of older earth-masses in Kilburn Peak, near Bellows Falls.

The valley is next continuous in the Ashuelot basin. The north rim lies between Paper Mill Village and Alstead Centre. The ridge in Marlow, where the old and new Forest roads unite, is 1,328 feet high, along the line of a railroad survey. Just north of the Ashuelot valley, near Alstead village, the ridge is lower, estimated to be about 900 feet. In Surry the valley is narrow and deep. In Keene it spreads out widely, the level at the railroad being 482 feet. It narrows in passing into Swanzey, but is constantly deepening. At Winchester the river turns into Hinsdale, across a very ancient ridge; but the valley continues into Massachusetts in a direct southerly course.

Principal Range. The main water-shed of the state is the eastern part of this double range. Leaving the White Mountain district in Moosilauke, it starts up again in the high Kinneo and Carr's mountains, running down through Wentworth and Rumney, ending in Rattlesnake mountain, till cut across by Baker's river.

Warren occupies an elevated position between the two great ranges. The general shape of the land is that of a basin, with notched edges. Just to the north the immense mass of Moosilauke makes a third side to the depression, while the narrowness of the Owl's Head pass nearly closes up the valley on the north-west. The map of Warren annexed,—kindly loaned by William Little, of Manchester, an early friend of the survey, and author of a history of Warren,—shows better than words the

topographical features of the town, with its ancient and modern artificial limits.

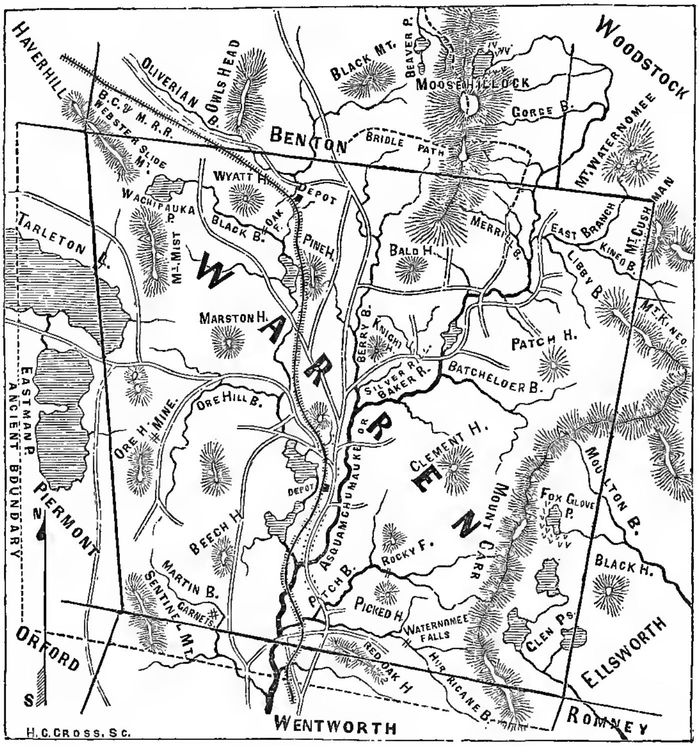


Fig. 40.—MAP OF WARREN.

Our main range rapidly recovers itself in the highlands of Groton, and Mt. Cardigan in Orange. The next low point is at the summit of the Northern Railroad. Next, we find, in Grafton, Isinglass mountain and Prescott hill. In Springfield the range is continuous in Aaron's ledges, Shad, Stevens's, Col. Sanborn, Hoyt, Sanborn, and Hog hills, besides others not mentioned on the map. The continuity is interrupted by the basin of Sunapee lake. Directly to the south are the Sunapee mountains, along the line between Newbury and Goshen. These connect directly with Kittredge, Jones, Taylor, and Ames hills, and Mt. Lovell in Washington. At the village the range is cut through by streams flowing south-easterly; but the ridge is continuous from Oak hill to Stoddard, the west part of Nelson, and so on to Mt. Monadnock.

Mt. Monadnock is usually described as an isolated peak rising out of a plateau, having the altitude of 3,186 feet; while the plain will average from 1,000 to 1,200 feet, including the towns of Jaffrey, Sharon, Fitzwilliam, New Ipswich, and others. While this is generally correct, it should be modified so that it be understood to be part of the principal backbone of the state, and the culminating peak of the southern part of the range. There are geological reasons for explaining its isolated position, which will be mentioned hereafter. The Pack Monadnock range is really a part of the Monadnock group. The Contoocook river, with its Harrisville branch, has excavated a deep channel through the Monadnock plateau, sinking northerly. Consequently there are left high hills to the west, as in Nelson and Hancock, Bald, Willard, and Robb mountains in Antrim, etc. On the east is the more important range of hills in the west part of Deering, Crotchet mountain in Francestown, Pinnacle mountain in Lyndeborough, Pack Monadnock in Peterborough and Temple, Temple, Kidder, and Barrett's mountains in Temple and New Ipswich. This is now the main range, having come from a direction east of north to join the Monadnock water-shed. It continues southerly into Massachusetts, viz., Watatic mountain in Ashburnham, Wachusett, 2,018 feet, in Princeton; and so on southerly through the central part of the state. The White Mountain range, therefore, when correctly followed, does not pass into the Connecticut valley Trap mountains, as maintained by some authors.

Heights along the Principal Water-shed of New Hampshire. The main water-shed of New Hampshire runs nearly parallel to Connecticut river, and in fact forms the eastern rim of that hydrographic basin. It is of special importance to one studying the topography of the state, and for that reason is given here as fully as possible.

From near the north corner of the state to Mt. Washington, this line skirts the Androscoggin basin. It borders the Saco waters only from Mt. Washington to Mt. Field. From here to Massachusetts the line agrees with the west border of the Merrimack system. The line may be divided into three sections: First, averaging 2,000 feet elevation to the base of Mt. Madison. Second, the White Mountain division from Madison to Moosilauke, averaging nearly 4,000 feet. Third, the portion from Warren to Massachusetts, averaging about 1,500 feet. The lowest point

in the northern section is at the Milan summit on the Grand Trunk Railway, 1,087 feet. The lowest point in the White Mountain line is at the notch, 1,914 feet. The Franconia notch is nearly the same, being 2,014 feet. The lowest point in the entire line is at the Orange summit of the Northern Railroad, 990 feet. The next lowest point is at Warren, 1,063 feet. It is followed by the railroad cut at Milan, 1,087, and at Newbury, 1,161 feet, for the natural surface of the ground. Two projected railway lines cross the southern section, with the height of 1,560 feet in Stoddard, and of 1,265 at Harrisville.

	Feet.		Feet.
Ridge between Lake Magalloway and Third lake,	2917	Gap between Washington and Monroe,	5100
Mt. Abbott (Kent), estimated,	2800	Lake of the Clouds,	5009
Mt. Carmel,	3711	Mt. Monroe,	5384
Two miles south of Second lake,	2030	Little Monroe, W.S.W. of Monroe,	5204
Magalloway mountain (est.),	2600	Mt. Franklin,	4904
Ridge (est.),	2500	Gap between Franklin and Pleasant,	4400
Mt. Pisgah,	2897	Mt. Pleasant,	4764
Near Diamond ponds, Stewartstown,	1723	Gap between Pleasant and Clinton,	4050
Dixville notch,	1858	Mt. Clinton,	4320
Table rock,	2454	Mt. Jackson,	4100
Peak in Erving's Location,	3156	Mt. Webster,	4000
Divide between Nash and Sims streams,	1715	White Mountain notch,	1914
Milan summit, G. T. R.,	1087	Mt. Willard (est.),	2570
Pond of Safety, Randolph,	1973	Mt. Field,	4070
Randolph mountain, Randolph,	3043	Divide between East Branch and New Zealand river,	2123
Divide between Moose and Israel's rivers, Randolph,	1446	Twin mountain,	4920
Mt. Madison,	5365	Gap (est.),	3000
Gap between Madison and Adams,	4912	Haystack,	4500
Mt. Adams,	5794	Mt. Lafayette,	5259
Gap between Adams and Jefferson,	4939	Franconia notch,	2014
Mt. Jefferson,	5714	Profile mountain,	3850
Gap between Jefferson and Clay,	4979	Valley (est.),	2850
Mt. Clay,	5553	Mt. Kinsman,	4200
Gap between Clay and Washington,	5417	Mt. Blue,	4370
Mt. Washington,	6293	Woodstock notch (est.),	1655
		Moosilauke,	4811
		Oliverian notch, B. C. & M. R. R.,	1063
		Webster Slide mountain, Warren,	2210

	Feet.		Feet.
Road over Ore hill, Warren, .	1542	Divide in road near Mud pond, Springfield, ...	1383
Piermont mount., Piermont (est.),	2500	Col. Sanborn hill (est.), . .	1600
Water-shed south-east of Indian pond, Orford, ...	1100	Divide between Little Sunapee and Pleasant pond, New London (est.), ...	1300
Mt. Cuba, Orford, . . .	2927	New London, ...	1355
Gap between Rocky pond, Wentworth, and Quinttown, Orford (est.), ...	1438	Between New London and Sunapee lake, lowest point, . .	1200
Smart's mountain, Dorchester (est.), ...	2500	N. W. corner of Sutton (est.),	1700
Dorchester valley, lowest point (est.), ...	1250	Chalk pond divide, Newbury (est.),	1260
Ridge east of Dorchester, Canaan valley, ...	2137	Railroad cut, Newbury summit, .	1130
Divide in road from Orange to Groton (est.), ...	1600	Ground above railroad cut, . .	1181
Hoyt hill, Orange (est.), . .	1700	Lowest natural ground 400 feet south of summit, . . .	1161
Orange summit, N. R. R., . .	990	Sunapee mountain, . . .	2683
Ford Hill, Grafton, . . .	1800	Ridge west of Washington vill.,	1463
Prescott hill, Grafton (est.), .	1700	Summit on Forest road survey, .	1560
Aaron's ledge, Springfield (est.),	1800	Stoddard, Coast Survey station,	2170
Divide in road from Springfield to Grafton (est.), . . .	1600	Harrisville, railroad summit level,	1265
High land to the south-east (est.),	1750	Mt. Monadnock, . . .	3189
		Kidder mountain, . . .	1492
		Barrett's mountain, . . .	1847
		Ashburnham summit, . .	1084

Other Elevated Areas. There are several important hilly areas in the Merrimack basin, immediately adjoining the range just described. The first is a hilly area in New Hampton and Sanbornton, consisting of Burleigh, Hersey, and Sanbornton mountains on the east side of the Pemigewasset. Next are the Ragged mountains of Andover and Hill. Separated from these by the Blackwater river are the Kearsarge mountains in Warner, Wilmot, and Salisbury, the most important of all the groups. Kearsarge resembles Monadnock in form, general features, and geological structure. Smaller areas worthy of notice are the dying out of the Ragged mountain range, with a southerly instead of easterly trend, in Franklin and Boscawen ; the Sutton hills, perhaps a continuation of Kearsarge ; an unnamed area in Bradford and Hillsborough, Mink hills in Warner, Craney hill in Henniker, with eminences in North Weare ; the Dunbarton heights, the Uncanoonucs of Goffstown, Joe English hill in

New Boston, Lyndeborough mountains, the hilly area of south-west Lyndeborough and Mt. Wilton, and the Rattlesnake hill granitic range of Concord. Perhaps the hilly character of Mt. Vernon, Amherst, Mason, and other localities may be worthy of notice.

On the east side of the Merrimack are several hilly groups, as Bean hill, Northfield, spreading into Canterbury on the south and into Gilmanton on the east; the somewhat isolated peaks of Grant, Bradford, and Cogswell hills, in the east part of Gilmanton; scattered summits in south-west Gilmanton and eastern Loudon, Catamount mountains in Pittsfield, Brush hill, McKoy's Fort, and Nottingham mountains in Epsom, with high land in the west part of Deerfield. Farther south the elevations are of less consequence. There is high land in Allenstown, extending in a range to Hooksett, and terminating in Campbell's hill near the Merrimack. There are minor ridges following the course of the two bands of quartzite, referred to on p. 50. The Manchester ridge runs a little east of north into the west part of Auburn and Candia, connecting with the abandoned railroad summit at Rowe's Corner, and the Allenstown range beyond. We can also trace an important ridge from Candia through Auburn, Chester, Derry East, and Windham, lying between Corbett's and Policy ponds just before entering Massachusetts.

The Lowland Country. There are no swamps nor low meadows of any consequence anywhere along the Merrimack river. The clay banks, when present, are usually high up, covered by sand. The high sandy plains commence in New Hampton. Here they are undulating and narrow. At Bristol they are cut off, and there is no correctness in Dr. Jackson's map, representing the great bend opposite Bristol as composed of drift. They skirt both sides of the river in Sanbornton, Tilton, Hill, and Franklin. In Northfield, Canterbury, Boscawen, and Concord we find the most extensive development of the elevated sandy plains. In the east part of Concord the plain is about one hundred and twenty-five feet above the river, and two miles wide. The plains are contracted to a line at Hooksett, widening in the south part of the town. The Piscataquog river develops this sandy plain several miles back into Bedford and Goffstown, from Manchester. Litchfield is chiefly a sandy plain. Merrimack, Amherst, Nashua, and Hudson possess large areas of the same, but the land so far down the river is everywhere low, and is mostly


WHITE M-T-S. FR. BERLIN

covered by hard pan, which has somewhat of a sandy character, and ought not to be confounded with the elevated plain above, for geological reasons. Every large tributary below Manchester, as the Souhegan and Nashua rivers, enlarges the bounds of the lowland, causing it to wind back among the border hills for many miles.

The valley of the Merrimack below Nashua in Massachusetts, in general terms, may be said to agree exactly with its physical features in New Hampshire below Manchester.

VI. *Coast Slope.* This greatly resembles the lower Merrimack country. It starts from the mountainous ridge bordering the Lake district on the south, and is bounded westerly by the Merrimack river basin. The northerly boundary consists of the following eminences, running in an easterly direction: Mt. Bet, Mt. Holly, Cropple Crown mountain, and Birch hill, with the Rattlesnake mountains for foot hills in New Durham; the Great Moose, Bald, Hall, and Parker's mountains in Middleton. The range is cut through by Fellows's branch of the Salmon Falls river in Wakefield (Union Village); and the hills to the east, in Milton, are low.

In general, it may be stated that the entire northerly and westerly borders of this district, as represented upon the map, are the lines of highest elevation, or the rim-edge of a basin, which slopes gently towards the ocean, having miscellaneous ridges and isolated peaks scattered at random over its surface. The first subdivision of this basin is a triangular area, widest at the north, with a very prolonged and swelling apex. It is situated between the Cochecho and Salmon Falls rivers, comprising New Durham, Middleton, Milton, parts of Wakefield, Farmington, Rochester, Dover, and the whole of the small towns of Somersworth and Rollinsford. Milton seems to have a culmination in Teneriffe mountain, near its topographical centre. Middleton and New Durham slope uniformly towards the two rivers, with lateral north-south ridges between tributary streams. The Rochester portion is a perfectly flat, sandy, swampy plain, 226 feet above the sea. In the laterally expanded apex of the triangle, there is a long elevation midway between the rivers, ending with Garrison hill in Dover.

A second subdivision may embrace the easterly flowing waters of the Cochecho. This includes the south-easterly, bearing "New Durham ridge" in the south corner of the town; the more extensive north east-south

west range of the Blue Job mountain in Farmington, and the Blue hills of Strafford; a north west-south east ridge, at right angles to the last, from Chesley mountain, in Farmington, to the west part of Rochester; and the extensive basin of Isinglass river, fed by Round, Long, Nippo, Stonehouse, and Ayer's ponds, in Barrington.

A third subdivision may be represented by the Lamprey river basin, including most of Northwood, Nottingham, Deerfield, and the vicinity of the Concord & Portsmouth Railroad. The first three towns mentioned show mountainous areas, as the Saddleback in the south part of Northwood, and the double group of Pawtuccawa in the west part of Nottingham, edging into Deerfield. In the east part of Nottingham there is a large marshy country tributary to Pawtuccawa pond. There is nothing of much importance in the rest of the Lamprey valley.

The fourth subdivision may be termed the Exeter river basin. This crooked stream rises in Chester, and flows through parts of Raymond and Fremont, where it is joined by another branch through Sandown, starting in Chester, thence through Brentwood and Exeter, joining Great bay between Newmarket and Stratham. After viewing the hills of Farmington and Middleton, there is nothing in this subdivision worthy of note.

The balance of this coast district may be called the Hampton division, embracing, perhaps, the most square miles of territory possessed by any of the five areas. It embraces three fourths of the land eastward from the Boston & Maine Railroad. The land is low, but not marshy, except along the shore line in Seabrook, Hampton Falls, and Hampton. The northern portion is a promontory between the Great bay and the Atlantic ocean. There is an extensive sea beach on it in Rye, with ledges on the coast at Little Boar's Head, Frost's Point, and Newcastle.

There is a peculiar class of drift hills observed in this area that do not occur far back from the ocean. They may be from eighty to two hundred feet above the adjoining lowland. They may be termed bowl-shaped or elongated ridges, according to circumstances. I have searched in vain for ledges about them, and have therefore concluded that they are entirely composed of drift brought from the north. I have reason to believe many of them exist in Rockingham county, a field that yet remains to be fully explored. Signal examples are in Stratham, in the north middle district, prominent on the map by reason of the absence of roads over it,

and in South Hampton abundantly. Great Boar's Head, in Hampton, is another example. Others occur in Massachusetts, as Prospect hill, Andover.

The Isles of Shoals belong to the coast slope, being remnants of land that may formerly have been connected with the main land. As they are little elevated above the tide, most of the loose materials have been washed away by the severe north-east storms occurring off our coast. I found on Star island boulders that had been derived from the main land thirty or forty miles distant.

Fig 41.—GEORGIANNA FALLS, LINCOLN.

CHAPTER VIII.

TOPOGRAPHY OF COÖS COUNTY.

BY J. H. HUNTINGTON.

THE extreme northern part of New Hampshire is covered by a continuous primeval forest; and the surface of the country is broken by undulating ridges, which here and there rise to mountain heights. In these forests, almost on the boundary of Quebec province, is the source of the Connecticut river; and in the extreme north-east corner of the state is a small lake, which is the principal source of the Magalloway river. Scarcely anything more is known to the dwellers on the banks of the Connecticut as to its source, than they know of the source of the Nile. Hence we shall give a somewhat minute description of this section.

The difficulties encountered in traversing an unbroken forest are many and varied. At times the experience is most pleasurable, and, again, obstacles are encountered that are almost insurmountable. To-day we cross a beautiful lake. The clear, sparkling waters reflect the bright sunlight, while along its borders are mirrored the trees that stand in stately grandeur on its shores. To-morrow its waters roll in tumultuous wave, and the clouds rest almost on the bosom of the lake. To-day we traverse its shores, and walk upon the soft green moss that lies spread under the trees of evergreen like a carpet, so soft and elastic to the

tread, while the rays of the sun, shining through the thick foliage, give a genial light, and the fresh green moss covers even the fallen trunks of the trees, as if to conceal every sign of decay;—and here, where a stream trickles over its mossy bed, one is carried away in elysian dreams, and forgets all else save that some enchantment binds him here. But to-morrow we become entangled in the undergrowth and shrubs, in what seems to be an illimitable morass; while the gently descending rain adheres to every spray of the foliage, and every touch brings down an additional shower to add to our discomfiture, until every thread of our apparel is saturated. As we struggle on through the underbrush and tangled ferns, we become bewildered as to our course, and our compass shows us that we are travelling in a direction exactly opposite to that we wished to go; and we conclude that this is certainly studying geology under difficulties. To-day we traverse a section where not a single rock is to be seen in place: to-morrow ledges that excite the liveliest interest crop out on every hillside. To-day the vision is circumscribed within the narrowest limits: to-morrow we ascend some lofty mountain, where the view is unobstructed, and where the undulations of the forests, as they stretch out in the far distance, seem like vast waves of the ocean; and nothing is more pleasing than to watch the shadows of the fleeting clouds as they pass over these miles of forests. To-day we see only the straight shafts of the spruce and fir: to-morrow the trees are varied, and along our pathway are plants of rare beauty,—orchids,—that would attract the attention of the most careless observer. To-day we see no sign of animal life, and the songs of birds, even, break not the stillness of these deep solitudes: to-morrow we may be carried away in ecstacies of delight as the song of the hermit thrush greets the ear, or we wonder at the extraordinary volume of song that the little winter wren pours forth; and, as we see its diminutive size, we mark the force of the comparison of the Indian who said that, if he had strength in proportion as this bird has power of song, he could move the world;—and it would not be strange if, in our travels through the woods, we should meet a deer or see a moose. To-day the cool breezes drive every insect from the air: to-morrow, in the dense forests, the mosquitoes are in perfect swarms, and their attacks drive one almost frantic. In the openings, where the mosquitoes cannot endure the sun, the black flies are sure not to be wanting. The very air

seems filled with them, and their attacks are, if possible, more persistent than those of the mosquitoes; and we are bled at every pore, so that the face becomes one mass of gore. To-night, after a delightful day, we camp beneath the clear blue sky, while the shimmering light of the moon through the trees gives a dreamy aspect to the scene; and, reclining on our elastic bed of boughs of fir, we need no somnific portion to bring sleep and repose. But again, another night, thoroughly saturated, we seek a camping-place, while the rain still pours in torrents. Stretching our shelter-tent, we kindle a fire with the bark of the birch trees, and, in the drenching rain, cut wood for our camp-fire. Then, retiring within our shelter, we steam until we are dry. So, day by day, the experience is ever new; but at no time is it an easy task to travel through the unbroken forests.

Water-sheds.

Along the water-shed that separates the head waters of the Connecticut and Magalloway from those of the St. Lawrence, runs the boundary line between New Hampshire and Quebec province. Although its general direction from Crown monument to the head of Hall's stream is a little south of west, yet so crooked is it that in its course it runs towards nearly every point of compass, making the distance nearly twice as great as it is in a direct line between these points.

At Crown monument the height of the water-shed is 2,568 feet. It descends gently for a short distance as we go west, but soon rises again, until, near Lake Magalloway, it has an elevation of 2,812 feet. The summit of the ridge here is 587 feet above the lake just mentioned. Then north-west of the lake there is quite a gap, but it soon rises again into a mountain ridge. But two miles west of the lake is another depression: in this rises the most north-westerly branch of the Magalloway. West of this the ridge rises again, and forms a mountain range which extends west two miles to the gap near Third lake. Extending south from this height of land is the water-shed between the Connecticut and Magalloway. The gap at Third lake has a height of 2,146 feet. Then there is a slight rise, and again a depression of about the same height as the last. Then the water-shed rises again to the summit of Mt. Prospect, to an elevation of 2,629 feet. It then descends, but continues with varying

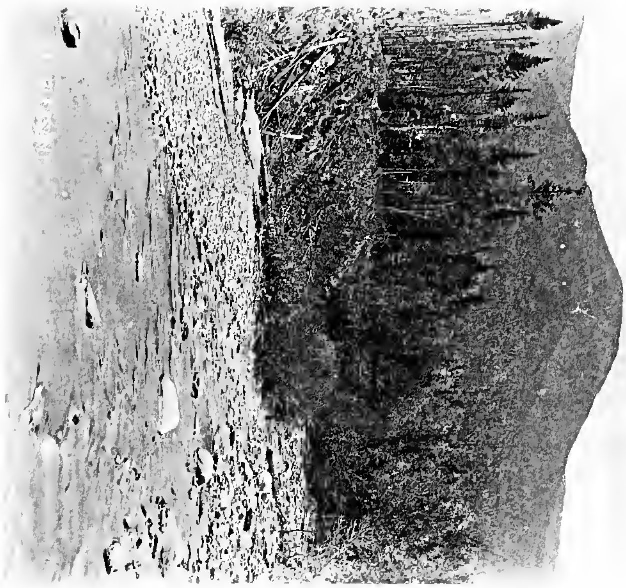
undulations, until, near the head of Hall's stream, it spreads out into an immense plateau.

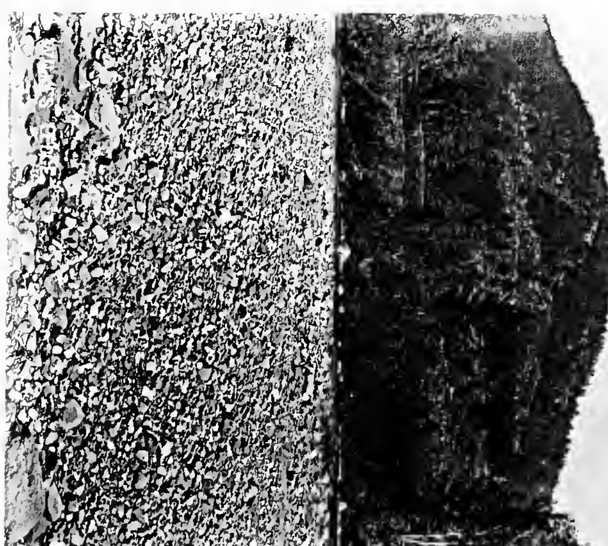
The water-shed that separates the waters of the Connecticut from the Magalloway, Androscoggin, and Saco rivers, runs as follows: Starting from the boundary of Quebec province, five miles south-west of Crown monument, and not far from three miles east of Third lake, the line runs nearly south four miles; then it turns almost directly east, and extends to Mt. Kent, on the boundary between New Hampshire and Maine; thence it follows the boundary to Mt. Carmel; thence it runs a little south of west, to a point two miles south of Second lake; thence south to Magalloway mountain; thence it follows a ridge west nearly a mile; thence it runs south-west to Mt. Pisgah; then it bends still to the west, and reaches its western limit near the Diamond ponds in the eastern part of Stewartstown; thence it runs south-east to Dixville notch; thence a little east of south, through the western part of Millsfield; thence south through Milan, Berlin, and Randolph; thence over the White Mountains to the notch. Along this water-shed is some of the highest land in New Hampshire; but there are occasional gaps where roads are or can be constructed. Some of these passes are well known. Going north from the notch, the first is in Randolph; the next is where the Grand Trunk Railway passes; then there is the road through Dixville notch; but north of this no carriage-road has ever been constructed,—and there are only three winter roads, and these for lumbering purposes. The first of these roads crosses the Connecticut three and a half miles south of Connecticut lake, and runs south-east. After passing the height of land, it strikes one of the branches of the Swift Diamond, and, following this, it extends down to the Magalloway. The second road begins at the last settlement in Pittsburg, crosses the Connecticut one mile north of Connecticut lake, and strikes the Magalloway four miles south of Parmachena lake. It is several years since either of these roads was used, but through the evergreen forests they are as distinct as when first made,—yet through the deciduous trees the underbrush has so obstructed the way that it is almost impossible to pass, even on foot. Along either of these routes there is nothing to hinder the construction of a carriage-road, and, probably along the most northern, one will never be called for; but it may be opened again

as a "tote" road when lumbering is carried on along the Upper Magalloway. The third, a new tote road, recently opened to the Magalloway by the way of Second lake, will probably be the one that will be most used, since it strikes farther up the river. The water-shed itself, and the country east, is broken up into irregular groups of mountains and hills, but no two groups have exactly the same kind of rocks. The axis of all the higher groups is either gneiss or schist.

The northern portion of the area of Vermont, that is represented on the topographical map, is covered for the most part with forests. In general, the features of the country are very irregular, and in the more rugged portions the land rises to mountain heights. On the east, Mt. Monadnock, in Lemington, is not far from 3,000 feet above the valley of the Connecticut, while in the towns immediately south of the Grand Trunk Railway there are half a score of mountain peaks. From this last area streams flow in every direction,—north into the Nulhegan, east into the Connecticut, and south and east into the Passumpsic.

The water-shed between the Connecticut and the St. Lawrence runs south-west from the head of Hall's stream through the township of Auckland, and when it strikes Hereford it runs nearly west almost to the limit of the township; thence it runs directly south about four miles, when it turns westerly into Barford; and thence it runs southward, and enters Vermont in the extreme west part of Canaan. It then runs south between Great Averill and Little Leach ponds. Between these the height of land is probably not more than fifty feet. From Great Averill pond it runs south perhaps a mile and a half below Little Averill, thence westward, bending northward around the head of the north branch of the Nulhegan, and strikes the Grand Trunk Railway in Warren Gore, when it turns abruptly southward and eastward, and strikes the Grand Trunk Railway again two miles south-east of Island Pond village. Southward the road from Island Pond to Burke crosses the water-shed near the southern line of Brighton; from thence it has generally a westerly trend, and the Passumpsic railroad crosses it in the north-west part of Sutton, when it passes out of the limit of our map. The great irregularity of surface in this north-east section of Vermont is due principally to the great difference in the character of the rocks. There are few areas of equal extent where so great a variety of crystalline rocks are found.





The Water Basins.

The northern portion of the water basin of the Connecticutt, he Magalloway, the Androscoggin, and the Saco, is embraced in this section. North of latitude 45° it embraces nearly the whole of that of the Connecticut. West of the Connecticut river, and north of latitude 45°, there are three nearly parallel ridges. The first, going west, is somewhat irregular, and is cut off where Perry's stream turns east and flows into the Connecticut. But two,—one between Perry's and Indian streams, and the other between Indian and Hall's streams,—are more uniform, and they have a mean height of about six hundred feet above the streams. South of latitude 45°, and east of the Connecticut, the ridges are everywhere very irregular. North hill, in Clarksville, rises 1,971 feet where the road crosses. South hill, in Stewartstown, is 2,000 feet, ascending to Jackson. In Colebrook and below, the high ridges branching from the water-shed have generally a westerly trend. South of Sims stream the ridge extends nearly to the Connecticut, as, also, the one in Stratford, south of Lyman brook. Below North Stratford the ridges run more to the south. In Northumberland, south of the Upper Ammonoosuc, they again run more nearly west, and continue thus until we reach Dalton, where the principal ridge runs north and south.

Seven miles south of Crown monument the water-shed touches the boundary line of Maine. The portion of the water basin of the Magalloway north of this is a level tract of country, penetrated by spurs from the boundary line towards Quebec province. South of the point mentioned above, the water basin of the Magalloway occupies a large tract of country in New Hampshire. It is everywhere broken into irregular mountain ridges, but these have generally a southern trend until we reach the Swift Diamond in Dartmouth College grant. South of this stream there is a high, continuous ridge from Dixville notch to the Magollaway: then there is a high ridge that runs south, parallel with the stream last mentioned. The triangular area, embraced by the Swift Diamond, Clear stream, and the Magalloway and Androscoggin, is a succession of hills and mountain ridges. The high point north of Dixville notch forms the apex of the triangle; and Mt. Dustan is in the north-east angle. South

of Clear stream the hills are, if possible, more irregular in their contour than those northward.

The Streams.

The principal streams are the Connecticut, the Magalloway, and the Androscoggin. Almost on the very northern boundary of New Hampshire, and nearly on the very summit of the dividing ridge that separates the waters of the St. Lawrence from those that flow southward, there is a small lake containing only a few square acres; and this is the source of the Connecticut river. It has an elevation of 2,551 feet, and is only seventy-eight feet below the summit of Mt. Prospect; and so remote is it from the habitations of men that it is rarely seen. A place more solitary I know not in northern New Hampshire. Surrounded as it is by dense forests of evergreen, you can see only these and the waters of the lake. Almost the only sound that relieves the monotony of the place is the croaking of the frogs, and this must be their paradise. A few steps to the summit of Mt. Prospect, and we can overlook thousands and thousands of square miles of forests in Quebec province, while in the extreme distance to the north-west can be seen the habitations of men. Southward the view is not extensive. The outlet of the lake just mentioned is a mere rill; this flows into Third lake. This lake is half a mile directly south of the boundary, and has an area of three fourths of a square mile, and its height is 2,038 feet. It is trapezoidal in shape, and has its greatest width on the south, while its northern shore is not more than a quarter of a mile in length. Its outlet is at the south-east corner, and its width is eight feet, and its depth six or eight inches. Besides the spruce and firs and cedars of immense size, it has a sub-alpine vegetation. Labrador tea, the *ledum palustre*, is found in abundance along its shores. In early summer, before the swarms of insects come, it is charming to stand upon its border, when not a ripple disturbs its placid waters, and the trees are mirrored along its shores. On every side except the south, the hills, which rise to mountain heights, approach almost to its very shores. The Connecticut, which is its outlet, is nowhere remarkably rapid. About five miles from the lake it receives a tributary from the east, the principal branch of which rises near the boundary. This stream is nearly as large as that into which it flows. A mile and a half from where it

receives this tributary, it flows into Second lake. This lake is two miles and three fourths in length, and in the widest part it is little more than a mile, and the height above the sea is 1882 feet. Its area is about one and three fourths square miles. It is one of the most beautiful of our northern lakes. The graceful contour of its shores, the symmetry of its projecting points, the stately growth of its primeval forests, the carpet of green that is spread along its border and extends through the long vista of the woods, the receding hills and the distant mountains, present a combination of the wild, the grand, and the beautiful that is rarely seen. Near its northern border, besides the Connecticut, it receives two tributaries, one from the north-east and one from the north-west. Its outlet is on the west side, near its southern limit; it is forty feet in width, and has a depth of eighteen inches. Twenty rods from the lake it has a fall of eighteen feet or more; then its descent is quite gradual, but forms here and there deep eddies. A mile from the lake it becomes more rapid, and rushes down between precipitous walls of rock in a series of wild cascades, which continue for half a mile. It receives two tributaries from the west before it flows into Connecticut lake. Here we find a sheet of water exceedingly irregular in its outline. Its length is four miles, and its greatest width two and three fourths, and it contains not far from three square miles. Its general direction is east and west, but near its outlet it turns towards the south. None of these lakes contain islands to any extent. Second lake has only one, and this has two, but they are very near the south-east shore. On the west shore of this lake the country is settled, and the grassy pastures extend down to its border; but for the most part it is still surrounded by a primeval forest. As many of the neighboring hills are crowned with deciduous trees, particularly the maple, in autumn, when the frost comes and these have put on their crown of beauty, of crimson and scarlet, of yellow and gold, and mingled as they often are with the dark foliage of the spruce and fir, we have a scene which, in brilliancy and beauty, is rarely if ever excelled. There is another element characteristic of this high elevation, for the lake is 1,619 feet above the sea. It often happens, when the forest has put on this robe of beauty, that all the neighboring heights are of immaculate whiteness from the frozen mist that clings to every spray of the evergreen foliage. Embraced in the picture are the blue waters of the lake, the belt of

deciduous forests, with their brilliant, gorgeous colors, the dark bands of the evergreens, and the snow-white summits. The water at the outlet flows over a rocky barrier, the stream falling abruptly nearly thirty-seven feet. The fall is quite rapid for two miles and a half: then the flow is more gentle for about four miles: then it becomes more rapid again, and continues thus until after it passes West Stewartstown. It is then nowhere a sluggish stream, and has rapids in many places until it gets below the falls of Northumberland: then it is the most placid of streams until it reaches the Fifteen-mile falls, which begin in Dalton. The fall from Connecticut lake to Lancaster is 785 feet. In New Hampshire, below Connecticut lake, the Connecticut river receives three large tributaries,—Perry's stream, which rises near Third lake, and has a rapid descent, including two falls three and five miles from its confluence, a mile and a half from the lake; Indian stream, which rises on the boundary, has a very rapid descent for five or six miles, when it is a very quiet stream until it flows into the Connecticut about eleven miles from the lake; Hall's stream, which rises also on the boundary, and is the dividing line between New Hampshire and Quebec province. Besides these there are several smaller streams. The principal streams from the east are Cedar stream in Pittsburg, Labrador brook and Dead Water stream in Clarksville, the Mohawk in Colebrook, Sims stream and Lyman brook in Columbia, Bog brook in Stratford, the Upper Ammonoosuc in Northumberland, Israel's river in Lancaster, and John's river in Dalton.

The Magalloway has its principal source in Lake Magalloway, about a mile and a half south-west of Crown monument. This lake is one of the most romantic in New Hampshire. It has an elevation of 2,225 feet above the sea. Its area is not far from from 320 square acres, and is surrounded by hills that rise to mountain heights, the elevation on the north-east being 587 feet above the lake, and from its summit we look immediately down upon it. The stream which is its outlet forms, a few steps from the lake, a beautiful cascade some twenty feet in height. Of all the men who have hunted in these forests, I have found only one who has ever seen this lake. If it were within the reach of travel, it would no doubt attract many persons, for in wildness and grandeur it is not surpassed. Its outlet is soon augmented by streams both from New Hampshire and Maine.

The Magalloway, soon after it enters the state of Maine, forms one of the peculiar streams in this northern country. It flows for a time with

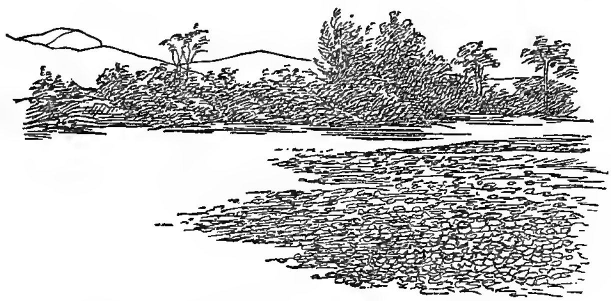


Fig. 42.—VIEW ON THE UPPER MAGALLOWAY.

a rapid current, and then for a long distance it is the most sluggish of streams, often deeper than it is wide, while on either side there are numerous ponds or bogs. Parmachena lake, into which it flows, is about the size of Connecticut lake. For four miles below Parmachena the stream is very rapid, and then, for almost the entire distance to Escahos falls, the descent is slight. Upper Magalloway settlement lies above the falls. The Magalloway enters New Hampshire in Dartmouth College grant. It flows about a mile, and then goes into Maine, but enters New Hampshire again in the north-east corner of Wentworth's Location, and flows into the Androscoggin a mile and a quarter from Umbagog lake. Although the river is very crooked, yet the water is of sufficient depth so that a steamer runs up nearly to the Maine line. The steamer runs down the Androscoggin to Errol dam: below this the Androscoggin is for the most part quite rapid, and, in the sixty-six miles of this river in New Hampshire, the fall is 464 feet. The tributaries of the Magalloway and Androscoggin from New Hampshire are the Little Magalloway, four and a half miles south of Parmachena lake, and the Swift Diamond, which has its source in the Diamond ponds in Stewartstown, and has a tributary, the Dead Diamond, which rises two and a half miles south-east of Second lake, and flows into the Swift Diamond a mile and a half from its confluence with the Magalloway in Dartmouth College grant. Clear stream flows into the Androscoggin in Errol. In Gorham the tributaries are Moose and Peabody rivers, the latter of which rises in the Great Gulf

between Mt. Washington and Mt. Adams. A considerable tributary, Wild river, rises in Bean's purchase, but flows into the Androscoggin in Maine. Besides these from the west, the Androscoggin has three tributaries in New Hampshire from the east,—the Molichewock in Errol, and the Chickwolnepy and Stearns brooks in Milan.

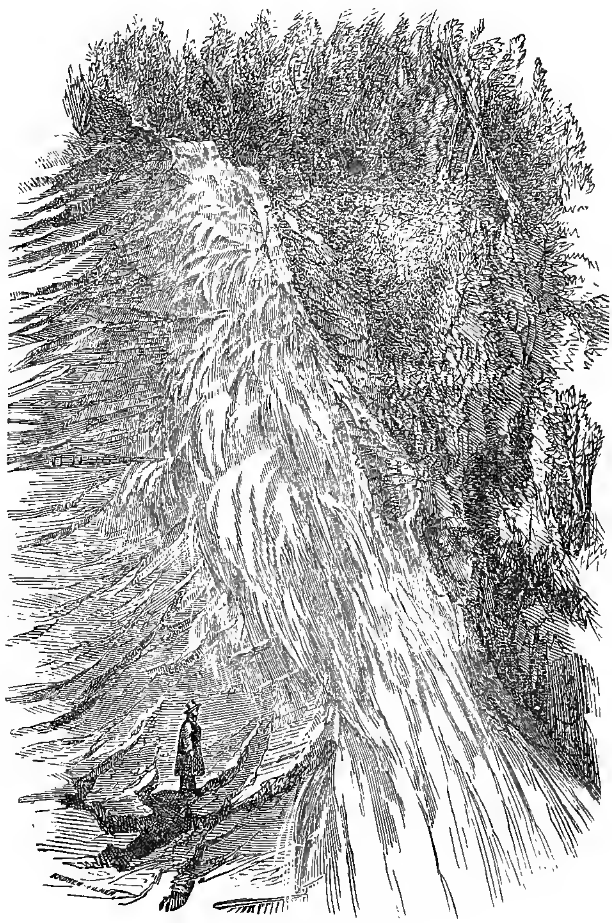


Fig. 43.—RIPLEY'S FALLS.

CHAPTER IX.

TOPOGRAPHICAL MAPS OF THE STATE.

ONE of the first essentials to a knowledge of the natural resources of a state is an acquaintance with its topographical features in relation to population. The position of villages, mountains, roads, streams, lakes, etc., must be known before any kind of important commercial transactions can be effected. Our predecessors understood the importance of maps, since they commenced a century since to order their construction,—long before many other states seemed to appreciate their importance. But a new one is needed now. We have endeavored to construct one that is reliable, drawing upon our own private resources for want of public patronage. It is employed as the base chart for representing the geology in this report.

In view of the importance of maps to the progress of civilization, I have thought it best to sketch the history of the official charts of New Hampshire, describing those in particular which have been published under legislative sanction, and stating the most important improvements in the one constructed under our direction.

The first known map of the state was edited by Joseph Blanchard and Samuel Langdon, and published at Portsmouth in 1761. I have not been able to find a copy of it anywhere, and therefore will not attempt to describe it. The next was Holland's. Dr. William Prescott, of Concord, possesses a copy of this, which has preserved much of its original fresh

appearance; and he kindly loaned it to us for examination and copy, by the heliotype process, for this report.

Holland's Map.

In 1773 and 1774, Capt. Samuel Holland made a survey of the province at the public expense. Owing to the disturbances, which commenced immediately afterwards, the map was not engraved till 1784, in London, and by the direction and at the expense of Paul Wentworth, Esq. Belknap says of it, in the third volume of his history, bearing date of 1792, in the preface: "Those parts which were actually furnished by Holland, or his assistants, are laid down with great accuracy. The eastern boundary line and the parts connected with it were not surveyed, but taken from such materials and information as could at that time be collected." Belknap has compiled a smaller map from Holland's for his work, upon which he placed a few improvements, including the straight line finally agreed upon by the assembly to take the place of the conspicuous "Masonian curve," appearing both upon Holland's and Carrigain's map. I quote Belknap's account of the final settlement of the matter.*

It was observed, in the course of the preceding work, that the Masonian proprietors claimed a *curve* line as their western boundary, and that under the royal government no person had controverted that claim. When the war with Great Britain was terminated by the peace of 1783, the grantees of some crown lands, with which this line interfered, petitioned the assembly to ascertain the limits of Mason's patent. The Masonians at the same time presented a petition showing the pretension which they had to a curve line, and praying that a survey of it, which had been made in 1768 by Robert Fletcher, might be established. About the same time the heirs of Allen, whose claim had long lain dormant for want of ability to prosecute it, having consulted council and admitted some persons of property into partnership with them, entered and took possession of the unoccupied lands within the limits of the patent, and, in imitation of the Masonians, gave general deeds of quit-claim to all *bona fide* purchasers, previously to the first of May, 1785,—which deeds were recorded in each county, and published in the newspapers. They also petitioned the assembly to establish a head line for their patent.

After a solemn hearing of these claims, the assembly ordered a survey to be made of sixty miles from the sea, on the southern and eastern lines of the state, and a *straight* line to be run from the end of one line of sixty miles to the end of the other. They

* Hist. N. H., vol. 3, p. 13. 1812.

also passed an act to quiet all *bona fide* purchasers of lands between the straight and curve lines, so far as that the state should not disturb them. This survey was made in 1787 by Joseph Blanchard and Charles Clapham. The line begins on the southern boundary, at lot No. 18 in the town of Rindge. Its course is N. 39° E. Its extent is 93½ miles. It ends at a point in the eastern boundary, which is seven miles and two hundred and six rods northward of Great Ossapy river. This line being established as the head line or western boundary of Mason's patent, the Masonians, for the sum of forty thousand dollars in public securities and eight hundred dollars in specie, purchased of the state all its right and title to the unoccupied lands between the straight line and the curve. The heirs of Allen were then confined in their claim to those waste lands only, which were within the straight line. They have since compromised their dispute with the proprietors of eleven of the fifteen Masonian shares, by deeds of mutual quit-claim and release. This was done in January, 1790.

The following is the title of the map upon its face:

A Topographical Map of the State of New Hampshire: Surveyed under the Direction of Samuel Holland, Esqr, Surveyor General for the Northern District of North America; by the following Gentlemen, his Deputies: Mr. Thomas Wright, Mr. George Sproule, Mr. James Grant, Mr. Thomas Wheeler and Mr. Charles Blaskowitz. London: Printed for William Faden, Geographer to the King. Charing Crofs, March first, 1784.

ADVERTISEMENT.

The respective parts of this Plan were arranged by the several Gentlemen concerned with all pofsible accuracy, and afterwards rectified by Samuel Holland Esq. from the Astronomical Observations made by him at Portsmouth, Wentworth House, Newbury Port and Cape Anne and those made by Mr. Wright at Hensdale and the Pine Tree at Dracutt.

By these Surveys thus adjusted the Form of the Province is exactly determined except as to its Eastern Boundary Line, which is laid down with the several Parts dependent thereon from such materials as were given in: Whatever relates therefore to that line, must depend on their authenticity and goodnefs.

The Bounds of the several Townships and Patents were delineated from Descriptions in the Public Offices, or Surveys made for the use of the State and the Parties concerned: It is pofsible some Tracts which were granted or patented at the execution of this Plan are omitted, should there be any such it must be attributed to the necefsary materials for describing them not having been sent in: Which is also the reason that some Townships appear more compleatly laid down than others that are perhaps as well settled.

Some of the special features of this map will be stated next.

Townships retaining the same names as at present, and the same, or not very different, boundaries:

Durham, New Market, Stratham, Exeter, Kensington, Lee, Epping, Raymond, Candia Parish, Windham, Pelham, Hollis, Mason, New Ipswich, Rindge, Fitzwilliam, Richmond, Winchester, Hensdale, Chesterfield, Westmoreland, Keene, Swanzey, Jaffrey, Dublin, Peterborough, Temple, Wilton, Lindborough, Amherst, Merrimack, Litchfield, Bedford, Goffstown, New Boston, Gillsom, Surrey, Walpole, Alstead, Marlow, Hilsborough, Henneker, Hopkintown, Wear, Concord, Bow, Dunbarton, Pembroke, Allen, Deerfield, Epsom, Northwood, Nottingham, Madbury, Dover, Chichester, Barnstead, Loudon, New Durham, Middletown, Wolfsborough, Tuftonborough, Moultonborough, Sandbourntown, Salisbury, Boscawen, Lempster, Atworth, Charlestown, Unity, Claremont, Newport, Cornish, Croyden, Plainfield, Grantham, Grafton, Alexandria, Plymouth, Holderness, Canaan, Hanover, Lime, Dorchester, Orford, Wentworth, Romney, Campton, Sandwich, Tamworth, Conway, Thornton, Piermont, Warren, Haverhill, Bath, Landaff, Whitefield, Lancaster, Northumberland, Colebrooke, Stuarttown, Shelburne, Dummer, Cambridge, Millsfield, Errol.

The following towns appeared without intervening boundaries, which probably were essentially their present ones: Newington, Portsmouth, Greenland, Rye, Hampton and Hampton Falls; Kingston, Newtown, Plaistow, Hampstead, New Salem (Salem and Atkinson), and Pelham; Brentwood and Fremont (Polin).

The following towns had about the same boundaries as at present, but different names: Hudson (Nottingham West), Manchester (Derryfield), Nashua (Dunstable), Brookline (Raby), Sharon (Peterborough Slip), Troy and Marlborough (Oxford), Nelson (Packersfield), Stoddard (Limerick), Washington (Camden), Newbury (Fishersfield), Sutton (Perry), Goshen and Sunapee (Saville), Springfield (Protectworth), New London (Alexandria Addition), Warner (Almsbury), Wilmot (Alexandria Overplus), Andover (New Britain), Wakefield (East-town), Effingham (Levits-town), Meredith and Laconia (New Salem, formerly Meredith), New Hampton and Center Harbor (Moultonborough Addition), Bridgewater and Bristol (New Chester), Orange (Cardigan), Groton (Cockermouth), Ellsworth (Trecothick), Woodstock (essentially Fairfield, but Benton included, partly), Lincoln and Franconia (Morristown, formerly Franconia and Lincoln), Enfield (Relhan), Lisbon (Gunthwait), Bethlehem (Lloyd Hill), Littleton and Dalton (Apthorp, formerly Cheswick), Carrol (Bretton Woods),

Jefferson (Dartmouth), Stark (Percy), Stratford (New Stratford), Columbia (Cockborne), Randolph (Durand), Gorham (Shelburne Addition), Berlin (Mainsburgh), Milan (Paulsburgh).

The following are marked off without names: Somersworth, the lower part of Ossipee, and Lebanon.

In addition to the territories embraced under their present appellations, the following towns included additional area: Rochester added Farmington and Milton; Barrington added Strafford; Chester added Auburn and Hooksett; Chichester included Pittsfield; Londonderry included Derry; "Society Lands" included Deering, Francestown, Antrim, Hancock, and Greenfield; Canterbury included Northfield; Gilmanton added Belmont and Gilford; Eaton embraced much of Ossipee, Madison, and Freedom. Kilkenny and Percy (Stark) seem to have been magnified to three or four times their proper width, and the straight east boundary is made to run due north and south. The White Mountain and Upper Coös regions were scarcely infringed upon by boundaries.

The importance of this map has induced us to reproduce it in the atlas as a *fac-simile* of one fourth the size of the original. For that reason, those interested in the changes of boundaries and names that have taken place since New Hampshire ceased to be a province of King George the Third, may glean further items of interest by actual inspection. For the same reason, it is not desirable to state, in detail, the position of the numerous gores and grants that have been absorbed into adjacent townships. I cannot forbear, however, to refer to the origin of the name Kearsarge. Holland says,—"Kyar Sarga mountain: by the Indians, Cowissewaschook." The name seems to have been derived from that of a Mr. Hezekiah Sargent,—corrupted by usage into Kearsarge. It is not, therefore, of Indian origin, as supposed by many. Furthermore, Kearsarge, in Warner, seems to have been the only mountain of that name in 1784. Hence, when the early settlers of Bartlett carried with them the name of their favorite mountain, and applied it to a new peak in Chatham, it cannot be expected that, in these days of rapid transit, we should employ the same name, or even the corruption of *Ki*arsarge, for the latter. It is best to retain the original name of Pigwacket or Pequawket, as I have endeavored to do uniformly in this report and on the new map.

A similar transfer of names is seen at Colebrook. A fine mountain,

Connected with this title is a large colored vignette, six by ten inches in dimensions. The title is inscribed upon the side of a shield-like cliff, with evergreens upon its summit, and an eagle feeding her young. Behind are several very high mountain peaks. On the left is a large cataract adjacent to the Willey house, and a hunter shooting at a moose on the border of a lake,—perhaps Winnipiseogee. On the right seems to be the ocean leading out of Portsmouth harbor, with a tower on an island, large ships, and a long arched bridge leading to Portsmouth. Nearer to the front is an extensive canal lock, and people engaged in agricultural operations,—ploughing and fishing. Directly in front of the title shield are miscellaneous objects, as cannon, the state insignia, rolls, baskets, etc. The name of the state is written in very large letters over the vignette, and the dedication is placed beneath. Three side sketches are the gap of the White Mountains, view of the Great Boar's Head with Hampton beach, and the White Mountains from Shelburne. Some of these will be reproduced with the map. Their vertical scale is so much exaggerated that they are objects of curiosity. There are two side maps, not reproduced: the first, of New England and the Dominion of Canada; the second, the United States as far as the Mississippi river. The early period of the issue of the map is appreciated, when it appears that Illinois, Indiana, and Michigan are represented here as territories. The following text on the side of the map, relating to the state, may be of historic interest.

NEW HAMPSHIRE is bounded on the E. by Maine, and the Atlantic; S. by Massachusetts; W. by the west bank of the river Connecticut as far as Lat. 45, and then by Lower Canada to Maine.

The line which divides New Hampshire from Maine, commencing at East Pond, and extending to the north-east boundary of the state, was taken from three surveys, made in 1741, 1768 and 1789; and is properly three lines.

The first surveyor allowed too much for the westerly variation; and the others, successively adhering, at the periods of their respective surveys to the same allowance, notwithstanding the continual retrogression of the needle, thereby increased the error, and actually made three distinct courses.

The royal order of 1740, by which this line should have progressed N. 2° W., has therefore never been carried into effect.

The southern boundary from the Pine, at the south-east corner of Pelham, to the river Connecticut, was measured in 1741, and was intended to have been a due west

line; but a similar allowance for the magnetic change having been adopted, gave it an inclination injurious to N. H. Yet how far the erroneous mode, then in practice, of running parallels by perpendiculars counteracted the mistake in the allowance for variation, remains to be determined by proper observations, yet to be made at the extremities of this line.

But under present circumstances the calculations of Mr. Wright, made in 1773, have been deemed from necessity the safest basis for this projection.

With regard to the face of the country, its features are striking and picturesque. The natural scenery of mountains of greater elevation than any others in the UNITED STATES; of lakes, of cataracts, of vallies, furnishes a profusion of the sublime and beautiful. It may be called the Switzerland of AMERICA. The extreme coldness of the winter is alleviated by the convivial hospitality of that season; and [is] more than compensated by the salubrity of the air and other delights of the summer. Industry morality and piety characterize the public manners, and this state richly participates in those advancements in science and that high grade of refinement, so general in NEW ENGLAND. Although the soil, for the most part, is better adapted to pasturage, than agriculture; yet a great portion of it is fertile, and produces maize and other grains abundantly. Elections are annual; the Townships are distinct corporations, and slavery is unknown. N. H. was discovered in 1614, and its settlement commenced in 1623. Its population had advanced in 1770 to 63,761, in 1780 to 102,131, in 1798 to 142,018, in 1800 to 183,663, and in 1810 to 214,460. The State is restricted to one harbor, which is at PORTSMOUTH, and is second to none in AMERICA. CONCORD is the present seat of Government.

The variation of the magnetic needle is given thus: Latitude 45, 1807, 7° 33′. Dartmouth college, 1808, 7° 21′. Concord, 1810, 7° 17′.

The scale is stated to be three miles to the inch, or rather that seems to have been the intention. Careful measurements upon our copy indicate it to be 3.4 miles to the inch. The variation is undoubtedly due to the contraction of the paper by drying after the impression had been printed upon it. Every map thus prepared is liable to modification for the same reason, and measurements should always be made from the scale engraved on the face of the map, rather than from a foot-rule.

The general appearance of the map is a great improvement over Holland's, having been engraved upon copper. The mountains, rivers, and various boundary lines are given with much greater precision. The northern boundary is given very nearly as it was finally settled by the commissioners. The wedge of Percy and Kilkenny, between the east and west townships in Coös county, has been reduced to respectable limits. Most of the grants and gores have been merged into townships;

and county lines are given for Rockingham, Hillsborough, Cheshire, Strafford, Grafton, and Coös.

Taking the town improvements over Holland's map by counties, it may be said of Rockingham that Canterbury and Chichester have been divided; Sandown, East Kingston, and Hawke (Danville) have been taken out of Kingston; Atkinson and Windham are eliminated; and the shore towns have their boundaries inserted. In Hillsborough, Mont Vernon and Milford came essentially from Amherst; Raby has become Brookline; Derryfield, Manchester; Peterborough Slip, Sharon. Only a half township of the "Society Land" is left unassigned. Warner, New London, Wilmot, Andover, and Sutton have received their present names. In Cheshire, Marlborough, Roxbury, Sullivan, Langdon, Washington, Goshen, and Springfield make their appearance for the first time. The present town of Sunapee is called Wendell.

In Strafford, Somersworth has a name; Rochester is divided as now. East Town becomes Wakefield; Ossipee, Center Harbor, Alton, Brookfield, New Hampton, and Burton (Albany) have an existence, because incorporated since 1784. In Grafton, Lebanon receives a name; Relhan becomes Enfield; Cardigan, Orange; Cockermouth, Groton; Trecothick and Fairfield are merged into Ellsworth, Peeling (Woodstock), and Coventry (Benton); Franconia and Lincoln are properly divided; Lisbon has the name of Concord; and Lyman remains as before, including the present town of Monroe. In Coös, Chatham, Adams (Jackson), Bartlett, Success, and Dixville are new townships. Shelburne is not divided as on Holland's; Dalton has been separated from Littleton (Apthorp); and there are six grants not previously mentioned. The names of Jefferson, Stratford, and Columbia are also new.

Both maps show the supposed course of the "ancient Masonian curve line." This will not be reproduced on the new map, as it has ceased to be of any practical importance, though it has apparently determined the west town lines of Fitzwilliam, Stoddard, and Washington.

Carrigain's map shows the population in figures engraved upon the face of each town. Kearsarge is applied where it belongs; and, in Chatham, Pigwacket mountain is said to have been formerly called Kiarsarge. There is an improvement over existing usage in regard to the Merrimack river. It is made to rise at the foot of Mt. Willey, and the name Merrimack is

applied to the east branch of the Pemigewasset. But the name of Pemigewasset is preserved as a synonym, as it should be. The stream coming down from Franconia is called the Middle Branch.

The roads are laid down well in accordance with the old method of presenting the general course, without reference to their minor irregularities.

Prof. Woodman's Report.

In 1853 the governor was directed to "appoint a commissioner to obtain the necessary information, and make estimates of the expense of constructing a new and accurate map of the state." In his report the following year, Prof. John S. Woodman, the commissioner, answers four questions, viz.,—What data, information, or facts are already within reach for the construction of a new map? What are necessary yet to be obtained for a new and accurate map by actual operations in the field? What is the time and expense necessary for obtaining all that is required, and constructing a map? What is the expense of engraving, printing, and manufacturing? The answer he gives to the second question expresses well the character of work required for the construction of a good map, and the deficiency of Carrigain's map in this respect.

An accurate map of a state is now understood to imply a map constructed upon data obtained by a series of geodetic and astronomical observations, carefully conducted with suitable instruments of the kind now in use for such work. Both instruments and methods have been greatly improved within fifty years, so that a degree of precision is now easily attained which was formerly impossible. The general method is briefly this: A base line of four to ten miles in length is accurately measured, and from this a series of large triangles is supposed to cover the state like a net. The sides of these triangles should be from twenty to forty miles long. The vertices of these triangles are accurately determined in position and elevation by the observations. Then a series of smaller triangles are taken so as to fix one or two points in or near such town. Then the town maps are accurately made and put in their true position by reference to the points determined by the triangulation. All the Coast Survey work in New Hampshire is so much work done, with the requisite care, and the distance between any two of these points can be used for a base, and the work readily continued over the state from the points in this state and on the adjacent borders of Maine and Massachusetts already established. The measuring of a base line with the required accuracy is always expensive, and would be particularly so in New Hampshire. The work of the Coast Survey that could be used without expense would probably diminish

the cost of the triangulation about one half. The exact determination of the principal points over the state, in this way, lies at the foundation of a correct map. The town maps and all the details can be prepared with more or less fulness and correctness, as may be convenient, and the state map improved from time to time till it is perfect, if the expense cannot be incurred at once. Slight errors in the position of the details would not greatly injure the map if the main points were all correct. But a map compiled from the best town surveys could not be relied upon as accurate. There would be likely to occur errors of some miles. In the copy of Carrigain's map now before me, by comparing the position of several points with their actual position as determined by the U. S. Coast Survey, they appear to be from ten to fifteen statute miles out of the way in longitude, and from one third of a mile to a mile in latitude. The large error in longitude has been partially corrected on later maps. The relative error is also considerable, though not more than what might exist in any map made in the same way. For instance, if Fort Constitution be assumed as correct in position, Uncanoonuc is more than a mile too far north and half a mile too far east, while Mt. Washington is two thirds of a mile too far south, and one third of a mile too far west. What remains to be done, then, to obtain the required data for an accurate map, is to complete the triangulation of the state, and make a correct plan of all the towns and places that have not yet been accurately surveyed.

Improvements Incorporated into the New Map.

Survey of the northern boundary by the United States government, in accordance with the treaty of 1842. Noticed upon pages 21, 171.

Operations of the United States Coast Survey south-east of a line from Mt. Washington to Mt. Monadnock.

Triangulation of several points under the direction of the geological survey in 1869. See full report further on.

Triangulation of the geodetic connection survey under the direction of the United States Coast Survey, E. T. Quimby, acting assistant. See page 47.

County maps. From 1855 to 1860 careful odometer surveys were made of every county in the state, and the results published by subscription. The scale was usually about an inch to the mile; and the most valuable portions of them relate to the delineation of the highways. Existing surveys of lakes, water-courses, boundary lines, railroads, and other topographical features were made use of wherever practicable. A map constructed simply from these odometer maps would produce a new draft much superior to Carrigain's, for the number of surveyors is greatly reduced, and there is consequently less opportunity for discrepancies

where different plans are matched together. These surveys cost over twenty thousand dollars, and their most valuable features are retained in the new draft.

Maps of the White Mountains by Bond, Boardman, and Guyot.

Two maps of Connecticut river, referred to on page 46.

Observations of detail by all who have been connected with the survey from the very first. Some of this has been referred to previously. Efforts have been made constantly to discover and correct every possible error, no matter how minute.

Maps of several tracts of forest land, particularly of Success, Cambridge, Errol, College grant, Carlisle, Pittsburg, Bean's purchase, Waumbek, Hart's Location, etc., furnished by the proprietors.

For the delineation of mountain ranges, use has been made of the facts given in the chapter upon Altitudes.

GEOGRAPHICAL POSITIONS DETERMINED BY THE COAST SURVEY.

NAME OF STATION.	LATITUDE.			LONGITUDE.		
From the Report for 1851.	°	′	″	°	′	″
Mt. Wachusett, Mass.,	42	29	18.32	71	52	53.34
Holt's hill, Andover, Mass.,	42	38	26.13	71	06	03.86
Thompson's hill, Mass.,	42	36	40.03	70	43	27.99
Uncanoonuc, Goffstown,*	42	58	58.34	71	35	18.83
Mt. Agamenticus, Me.,	43	13	22.90	70	41	11.75
Mt. Patuccawa, Nottingham,*	43	07	12.206	71	11	50.60
Mt. Gunstock, Gilford,*	43	31	03.00	71	22	10.697
Ossipee, Me.,	43	35	17.23	70	44	06.54
From the Report for 1853.						
Isles of Shoals,	42	59	13.06	70	36	29.07
Stratham hill,	43	02	20.75	70	53	05.18
Hampton Falls,	42	54	42.54	70	53	30.80
Great Boar's Head,	42	55	03.61	70	47	24.80
Hampton,	42	56	32.14	70	49	16.82
Little Boar's Head,	42	57	27.07	70	46	12.69
Hampton academy,	42	56	00.23	70	49	46.52
Hampton, Orthodox church spire,	42	56	12.76	70	49	41.32
Hampton, Baptist church spire,	42	56	15.00	70	49	52.15
Hampton, wind-mill,	42	56	16.03	70	49	23.48
Hampton Falls, academy,	42	54	57.87	70	51	34.54
Hampton Falls, church tower,	42	54	59.03	70	51	33.96
Seabrook, Orthodox church spire,	42	54	10.22	70	51	45.41
White Island light,	42	58	00.40	70	37	04.63
Smutty Nose island,	42	58	56.87	70	35	51.87
Star island,	42	58	29.05	70	36	26.49

*The geographical positions as given in the earlier reports do not agree exactly with the latest determinations, especially of the longitudes. The ocean telegraph has furnished the means of ascertaining more accurately than before the difference in time between Greenwich and Washington. The average correction to be added to the longitudes is 20″.15, and 0″.28 to the latitudes. In the cases above, that are marked with an asterisk, I have given the latest figures of the Coast Survey, but have not corrected any of the others.

NAME OF STATION.	LATITUDE.			LONGITUDE.		
From the Report for 1853.	°	′	″	°	′	″
Star Island church,	42	58	33.60	70	36	30.89
Jennis ledge,	42	58	26.41	70	45	36.11
Locke's point,	42	59	29.05	70	44	45.51
Foss,	43	00	44.02	70	44	00.14
Breakfast hill, Rye,	43	00	23.72	70	48	11.22
Rye, Orthodox church spire,	43	00	38.53	70	46	03.44
Rye, Baptist church spire,	43	00	42.72	70	46	02.39
Pulpit rock,	43	01	56.75	70	42	47.15
Newcastle,	43	03	35.32	70	42	59.33
Newcastle light,	43	04	14.33	70	42	11.76
Fort Constitution, flag-staff,	43	04	16.26	70	42	13.52
Whale's-back light,	43	03	29.91	70	41	27.89
East end of base of survey by U. S. Top. Eng'rs,	43	02	33.71	70	42	25.95
Seward,	43	04	09.41	70	40	23.73
Newmarket,	43	03	22.32	70	56	00.94
Frost's hill,	43	09	43.25	70	47	02.81
Wentworth,	43	08	22.94	70	51	38.32
Great hill,	43	05	21.87	70	45	00.67
Newington,	43	05	50.57	70	49	50.60
Newington church,	43	05	52.09	70	49	39.41
Stratham, Orthodox church spire,	43	01	03.72	70	54	44.83
Stratham, Baptist church tower,	43	01	38.57	70	54	19.07
Woodman's point,	43	04	22.71	70	51	14.17
Durham,	43	05	17.69	70	53	17.76
Durham spire,	43	07	57.14	70	55	01.83
Greenland, Orthodox church spire,	43	02	10.70	70	49	40.87
Greenland academy,	43	02	00.01	70	49	41.52
Brooks,	43	06	38.86	70	46	58.25
Bartlett,	43	05	23.96	70	46	28.86
Poverty Heights,	43	04	55.14	70	46	30.04

In the report for 1868, the cupola of Mt. Pequawket is given as latitude 44° 6′ 19″.60; longitude 71° 5′ 20″.22. I learn the following to be the position of Mt. Washington: Latitude 44° 16′ 25″; longitude 71° 16′ 26″. Mt. Monadnock, in accordance with the latest determinations, has latitude 42° 51′ 39″.61; longitude 72° 6′ 30″.49.

Prof. Quimby's Report.

To Prof. C. H. Hitchcock: I beg leave to submit the following report of the geodetic work done by your order the past year. I occupied, during the month of October, 1869, the following stations, and, although the weather was very unfavorable, succeeded in obtaining satisfactory observations on each: The observatory at Dartmouth college; Moose mountain, Hanover; Kearsarge, Warner; Uncanoonuc, Goffstown; Monadnock, Jaffrey; and Ascutney, Windsor, Vt. The station upon Kearsarge was at an angle of the line between the towns of Warner and Wilmot.

The subjoined table and plan will give you the results of this survey, without adjustment by the method of least squares, which may be applied if the work should be carried further. The values marked * were obtained from the U. S. Coast Survey.

STATION.	ANGLES.	SPH. EX.	DISTANCES IN METRES.	DISTANCES IN MILES.	TO STATION.
Monadnock,	52° 49′ 49″.535		44548.677*	27.68	Uncanoonuc.
Uncanoonuc,	81° 23′ 28″.635	5″.58	49553.216	30.78	Kearsarge.
Kearsarge,	45° 46′ 47″.41		61461.211	38.19	Monadnock.
Monadnock,	42° 28′ 21″.00		61461.211	38.19	Kearsarge.
Kearsarge,	79° 00′ 05″.5	7″.5	48658.460	30.24	Ascutney.
Ascutney,	58° 31′ 41″.00		70738.541	43.96	Monadnock.
Ascutney,	60° 05′ 18″.46		48658.460	30.24	Kearsarge.
Kearsarge,	51° 10′ 40″.96	4″.39	45258.533	28.12	Moose.
Moose,	68° 44′ 04″.97		40680.346	25.28	Ascutney.
Ascutney,	13° 00′ 25″.347		40680.346	25.28	Moose.
Moose,	36° 11′ 58″.547	0″.741	12093.886	7.51	Observatory.
Observatory,	130° 47′ 36″.847		31735.233	19.72	Ascutney.

LATITUDES, LONGITUDES, AND AZIMUTHS.

STATION.	LATITUDE.	LONGITUDE.	AZIMUTH.	TO STATION.
Monadnock,	42° 51′ 39″.611*	72° 06′ 30″.489*	252° 07′ 58″.403*	Uncanoonuc.
			199° 18′ 08″.868	Kearsarge.
			156° 49′ 47″.868	Ascutney.
Uncanoonuc,	42° 58′ 58″.338*	71° 35′ 18″.825*	72° 29′ 13″.015*	Monadnock.
			153° 52′ 41″.650	Kearsarge.
Kearsarge,	43° 22′ 58″.53	71° 51′ 27″.81	19° 28′ 25″.954	Monadnock.
			98° 28′ 31″.454	Ascutney.
			149° 39′ 12″.414	Moose.
			333° 41′ 38″.544	Uncanoonuc.
Ascutney,	43° 26′ 45″.39	72° 27′ 08″.42	204° 58′ 16″.361	Observatory.
			217° 58′ 41″.708	Moose.
			278° 04′ 00″.2	Kearsarge.
			336° 35′ 41″.168	Monadnock.
Moose,	43° 44′ 2″.972	72° 08′ 29″.70	38° 11′ 33″.205	Ascutney.
			74° 23′ 31″.752	Observatory.
			329° 27′ 28″.232	Kearsarge.
Observatory,	43° 42′ 17″.22	72° 17′ 9″.99	25° 05′ 17″.289	Ascutney.
			254° 17′ 40″.342	Moose.

It is proper to say that the latitude of the Shattuck observatory, Dartmouth college, as obtained by this survey, differs only 2″ from the latitude as determined astronomically by Prof. Young, and the longitude differs only 1″.25 from the astronomical longitude as far as has been yet determined;—and even this discrepancy is no doubt due to the station error

of the observatory. The instrument used in the survey was a ten-inch theodolite belonging to the Thayer School of Engineering, Dartmouth college. The signals used were heliotropes, which were kindly loaned for this purpose by the United States Coast Survey.

Respectfully submitted, E. T. QUIMBY.

GEODETIC CONNECTION SURVEY.

DARTMOUTH COLLEGE, April 1, 1874.

DEAR SIR: I am instructed by the superintendent of the United States Coast Survey to furnish you any information you may desire from the results of the triangulation of New Hampshire. It is desired that you state, in publishing these results, that they are obtained by the first rough computations, and will doubtless be somewhat modified by the final adjustments. I have occupied, for observations, twelve stations in the three seasons which have been given to the work, and observations have been made upon several hundred stations. By an appropriation made by the state the work has been greatly facilitated and extended, in the establishment of tertiary stations. The number of geographical positions already determined is fifty, the altitudes of which have also been found by trigonometrical levelling. Besides these, many others have been observed from one direction, and will only require observing from another point to give their latitudes and longitudes.

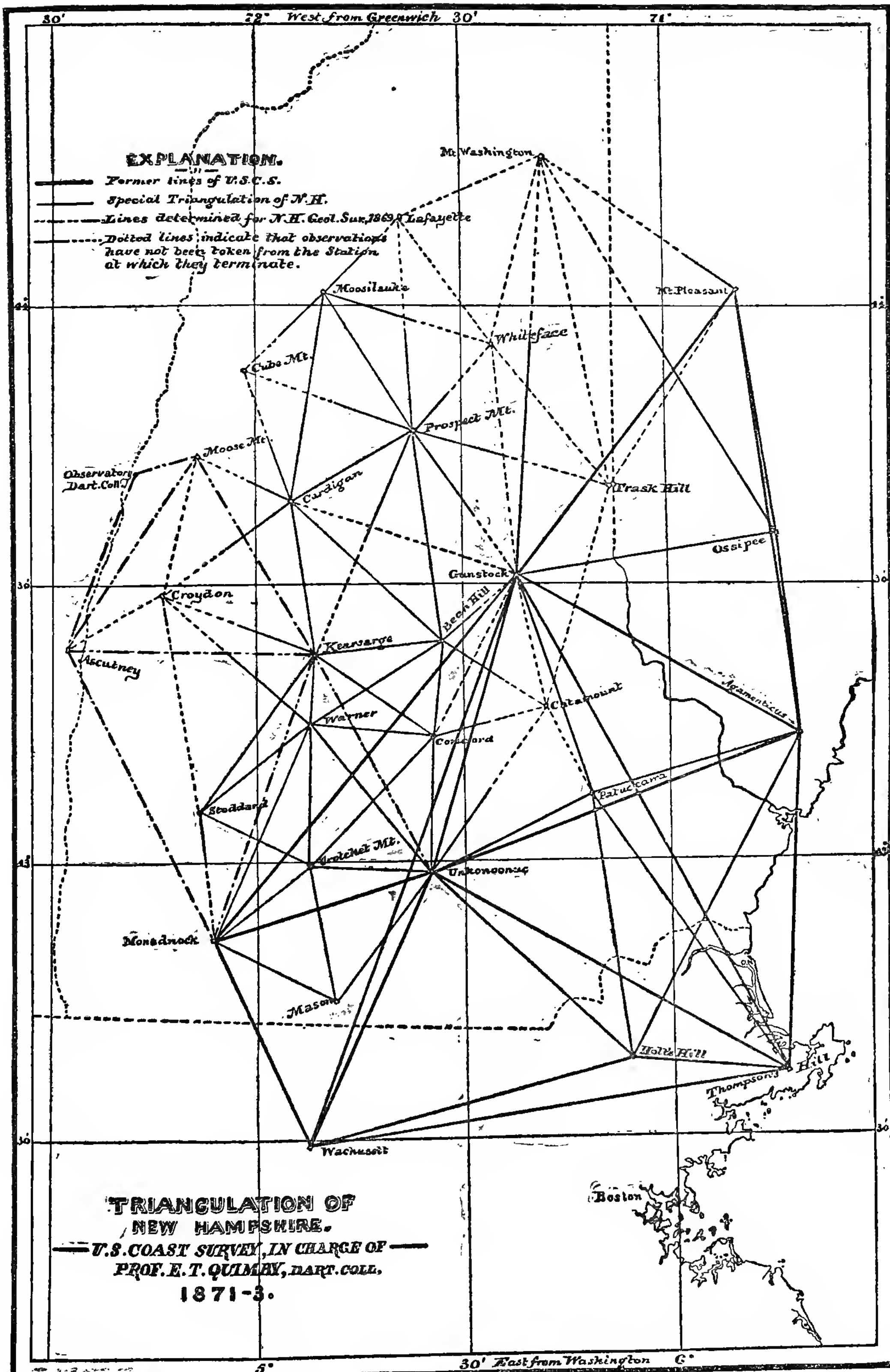
The accompanying chart shows the scheme of this triangulation and the progress thus far, and the former Coast Survey stations with which it is directly connected. The stations here shown are only those occupied as points of observation, the tertiary points being too numerous to be shown on a chart of this size. The base from which this triangulation proceeds is the line Monadnock–Uncanoonuc. Although these results, as above mentioned, are not to be considered final, it may be remarked that the latitude and longitude of Gunstock, as computed from the base Monadnock–Uncanoonuc, through this triangulation, differ from the former results of the Coast Survey only 00″.03. From this it would seem that the correction made by the final adjustment will not be large. Respectfully yours,

E. T. QUIMBY,
Acting Assistant U. S. C. S.

PROF. C. H. HITCHCOCK, *State Geologist.*

LATITUDES, LONGITUDES, AND ALTITUDES, U. S C. S.

STATION.	Latitude.	Longitude.	Height in Feet.	OBJECT WHOSE HEIGHT IS GIVEN.
	° ′ ″	° ′ ″		
Barrett hill, Greenville,	42 45 08.21	71 48 45.54	1271	Ground at signal.
Nelson pinnacle, Nelson,	42 59 49.8	72 05 52.1		
Tuttle hill, Antrim,	43 03 49.1	72 00 22.0		
Bald mountain, Antrim,	43 01 18.2	72 01 52.8	2039	Ground at signal.
Pack Monadnock, Peterboro',	42 51 43.7	71 52 45.0	2289	" "
Mont Vernon church spire,	42 53 32.6	71 40 27.7		
Bald Mink, Warner,	43 15 23.1	71 50 34.4	1528	Ground at signal.
Peterborough town-house,	42 52 37.8	71 57 03.6		
Greenfield church spire,	42 57 02.4	71 52 20.1		
Dublin church spire,	42 54 20.8	72 03 38.6		
Deering pinnacle, Deering,	43 04 22.6	71 52 12.8		
Craney hill, Henniker,	43 09 01.2	71 47 54.6	1420	Ground at signal.
Barrett mt., New Ipswich,	42 45 42.8	71 54 56.1	1847	" "
Duncan hill, Hancock,	42 58 06.1	72 02 11.7	2003	" "
Antrim south church,	43 01 52.9	71 56 19.4	766	Middle of belfry window.
Antrim brick church,	43 02 53.2	71 55 34.1	718	Ridge-pole of church.
Sunapee mt., Newbury,	43 17 56.3	72 03 50.8	2683	Ground at signal.
North Putney hill, Hopkinton,	43 13 02.9	71 41 24.9	827	" "
Shaker barn, Canterbury,	43 21 32.0	71 29 22.3	697	Ridge-pole of big barn.
Corser hill church, Webster,	43 19 46.6	71 42 58.4	786	Top of steeple dome roof.
State house, Concord,	43 12 23.8	71 32 18.1	434	Gold ball above dome.
Fort mountain, Epsom,	43 11 02.8	71 19 11.1	1428	Ground at signal.
Cong. church spire, Pembroke,	43 08 54.8	71 27 34.6	446	Base of spire where it joins the roof.
Lovell's mt., Washington,	43 12 11.2	72 03 42.5	2487	Ground at signal.
Crotched mt., Francestown,	42 59 52.58	71 52 26.71	2066	" "
Pitcher mt., Stoddard,	43 05 37.3	72 08 07.4	2170	" "
Catamount mt., Pittsfield,	43 16 30.2	71 17 45.0	1341	" "
Rattlesnake hill, Concord,	43 13 41.04	71 34 19.92	783	" "
Stewart's peak, Warner,	43 15 04.30	71 52 04.07	1808	" "
Gilmanton peak, Gilmanton,	43 25 27.3	71 23 55.5	1479	" "
Sanbornton Square town-house,	43 29 37.1	71 35 01.9	930	Ridge-pole of town-house.
Ragged mountain, Andover,	43 28 01.7	71 50 04.2	2256	Ground at signal.
Croydon mt., Croydon,	43 28 53.7	72 13 11.4	2789	" "
Kearsarge mountain, Warner,	43 22 58.44	71 51 27.69	2943.5	" "
Bean hill, Northfield,	43 23 47.97	71 32 48.90	1515	" "
Prospect mt., Holderness,	43 46 41.39	71 36 56.57	2072	" "
Cardigan mountain, Orange,	43 38 57.31	71 54 52.52	3156	" "
Bristol peak, Bristol,	43 37 56.3	71 42 05.0	1785	" "
Melvin hill, Springfield,	43 31 33.0	71 59 18.8	2134	" "
Ford hill, Grafton,	43 34 11.0	72 01 00.6	1800	" "
Red hill, Moultonborough,	43 45 20.0	71 27 28.9	2038	" "
Black mountain, Sandwich,	43 54 00.5	71 29 54.4	3999	" "
Tallest church spire, Laconia,	43 31 45.5	71 28 16.7	568	Ridge-pole.
Stinson mt., Rumney,	43 50 07.5	71 47 09.9	2707	Ground at signal.
Cong. church spire, Thetford, Vt.,	43 49 08.6	72 13 47.6	1024	Top church spire dome.
Mt. Cuba, Orford,	43 53 07.6	72 01 26.4	2927	Ground at signal.
Whiteface mt., Waterville,	43 56 00.1	71 24 21.4	4007	" "
Lafayette mt., Franconia,	44 09 37.8	71 38 41.0	5259	" "
Moosilauke mt., Benton,	44 01 23.07	71 49 54.92	4811	" "
Church spire, Deering,	43 03 58.5	71 51 21.5		



30'
72°
West from Greenwich
30'
71°
EXPLANATION.
Former lines of U.S.C.S.
Special Triangulation of N.H.
Lines determined for N.H. Geol. Sur. 1869.
Dotted lines indicate that observations have not been taken from the Station at which they terminate.
Mt Washington
Lafayette
Moosilauke
Mt Pleasant
Whiteface
Cube Mt.
Prospect Mt.
Moose Mt.
Observatory Dart. Coll.
Cardigan
Trask Hill
Ossipee
Gunstock
Croydon
Beck Hill
Ascutney
Kearsarge
Agamenticus
Catamount
Warner
Concord
Stoddard
Patuckaway
Crotched Mt.
Uncanoonuc
Monadnock
Mason
Holt's Hill
Thompson's Hill
Wachusett
Boston
TRIANGULATION OF NEW HAMPSHIRE.
U.S. COAST SURVEY, IN CHARGE OF PROF. E. T. QUIMBY, DART. COLL.
1871-3.
5°
30' East from Washington
6°

For the sake of facilitating further determinations, I present also the directions for the selection of tertiary stations. Persons who desire to obtain the exact positions of conspicuous landmarks in the vicinity of Prof. Quimby's work, only need to follow these directions, and in due time they will receive the results of the calculations.

Directions for the Selection of Tertiary Stations and the Erection of Signals for the United States Coast Survey, and the operations connected therewith.

1. Tertiary stations should be upon those hills which command the best view of the surrounding country, particularly within a radius of six to ten miles. It is not so important to secure a distant view as that the signal should be visible from the valleys in the more immediate vicinity. It must also be visible from at least three secondary stations.

2. Having chosen the hill upon which a signal is to be erected, select that spot for the station where the signal can best be seen from all directions, taking care that the ground be as level as possible for a few feet around the station, for the convenience of placing an instrument over it.

3. The method of marking permanently the station will depend on the nature of the ground. If the ledge is within three feet of the surface, remove the earth and drill a five-eighths inch hole four inches deep, in which set with lead or sulphur an iron bolt projecting three inches above the ledge. If the ledge is near the surface, cut a small equilateral triangle in the rock around the bolt (say each side nine inches), one of the sides being north and south, and the opposite vertex pointing to the east.

If there is no ledge within three or four feet of the surface, dig to that depth and set a stone jar or some piece of pottery which will accurately mark the station, and be readily recognized when found. Pack the earth carefully around and above this to the depth of twelve inches, upon which place a piece of plank with a half-inch bolt firmly set in it and projecting upwards three inches exactly over the station, as marked by the jar.

4. Select for the signal a straight pole (from which it is better to remove the bark) six or eight inches in diameter at the butt, and twelve or fifteen feet long. Bore a hole in the centre of the butt to receive the bolt set in the ledge or plank, and fasten to the top of the pole a nail keg, ten to fifteen inches in diameter, so that the centre of keg and pole shall coincide. This may most readily be done by inverting the keg (one head being out) upon the pole and nailing through the other head, at the same time bracing firmly the lower end of the keg. Cover this keg with black cambric, and the pole below the keg with alternate bands of white and black. Set the pole thus prepared over the bolt, and support it in a vertical position by filling around with earth, or if on a ledge by a pile of stones, and also by braces or wire guys, as the circumstances permit or require. Too great care cannot be taken to place the pole exactly vertical, and to secure it from being moved by winds, cattle, or any other cause. To secure

verticality, use a plummet from two directions at right angles, and avoid any deviation of the plummet by the wind.

5. To aid in finding the station if the signal pole should be removed, a full description must be made, embracing the following points:

The township and county in which it is situated; the most direct and easy route for reaching it; the name by which the hill is commonly known; the name of the person owning the land where the station is; the name and post-office address of the person having the signal in charge (who is expected to restore it to its proper position, if disturbed); the particular part of the hill where it is located; its exact distance and magnetic direction from any prominent objects around; the height of the top of the keg above the ground; the manner in which the station is marked, whether by bolt or jar; and any other statements which may facilitate the identification of the spot whenever the signal may be destroyed.

In this description there should also be noted the direction, by the compass, to other hills and mountains visible, particularly to those upon which signals have been or are to be set, also, to church spires and other prominent buildings. This description should be carefully written out and sent to

PROF. E. T. QUIMBY,
Acting Assistant U. S. C. S., Hanover, N. H.

MISCELLANEOUS.

It is perhaps hardly important enough to mention reasons for choosing particular names of localities when there is opportunity to exercise judgment. For example, in opposition to a common usage, I employ Mt. Cuba instead of Mt. Cube, in Orford. According to Dr. Dwight,* the original name was derived from the circumstance that a dog called Cuba lost his life on this eminence in a fight with a bear. There is no significance in the word Cube, save as a corruption of Cuba. I retain the improvement proposed by Carrigain in applying the appellation of Merrimack river to the longest branch of the Pemigewasset. A pond at the north-west head of the Magalloway river we propose to call Magalloway pond or lake. Small bodies of water discovered in the White Mountains are termed Haystack and Kinsman ponds. Mts. Hale, Field, and Lyon are new names suggested for peaks in Pemigewasset and Northumberland. Any other changes of consequence will be noticed in connection with descriptions of their geological or physical features.

The proper triangulation of the White Mountain district is likely to

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* Travels in New England, vol. ii, p. 119.

alter the dimensions of many tracts of land. The case of Kilkenny has been referred to. Another is the position of Mt. Passaconnaway. The western line of Albany, as perambulated, according to James Shackford, lies west of this mountain; but the triangulation will bring it and Whiteface into the town of Waterville. This discrepancy has not been observed before. There may be others of a similar character. While we exercise our judgment in locating every point according to our information, we rejoice that our map is not the legal tribunal for the settlement of discrepancies.

There are irregularities in the mutual boundaries of Carroll, Grafton, and Coös counties, which will probably need rectification from the legislature. The limits are given thus in the General Statutes, p. 67:

Carroll. "Thence by the northerly line of Sandwich to the westerly line of Albany; thence by the westerly line of Albany to the north-west corner thereof; thence by the *north* line of Albany to the *west line of Bartlett; thence by the west lines of Bartlett and Hart's Location to the north line of said Location; thence by the northerly and easterly lines of said Location to the west line of Bartlett;* thence by the westerly lines of Bartlett and Jackson to the northerly line of Jackson," etc.

Grafton. "Thence on the westerly and southerly lines of Dalton, Whitefield, Carroll, and *Nash & Sawyer's Location, to the south-easterly corner thereof; thence southerly on a straight line across the unlocated lands to the line of the county of Carroll at the north-westerly corner of Albany,*" etc.

Coös county "contains all the lands and waters within the limits of this state which lie northerly of the counties of Grafton and Carroll."

The boundaries as defined above leave a triangular area, about half a township in size, outside all county lines. It lies between the straight easterly boundary of Grafton and Hart's Location. This straight line also cuts off a part of Hart's Location, making a small area of land to lie in two counties. The Carroll county map places the neglected area and the south projection of Coös county between Hart's Location and Bartlett with Jackson, within its own limits. Perhaps this is the best disposition to be made of these unsettled areas, though we can find no authority for such a reference. Any other arrangement lacks symmetry of outline.

There is a question in relation to the proper boundary line between the Atkinson and Gilmanton Academy and Carlisle grants. The act defining the former fixes the northerly boundary on the line of forty-five degrees north latitude.

Carlisle's grant is defined thus: Commencing at east bank of Connecticut river at point of intersection with the north line of the College grant (Clarksville); "thence extending up said river, on the east side thereof as it winds and turns, to the distance of twelve miles in a straight line from the place of beginning; thence in a line as nearly as possible at right angles with the main course of the aforesaid line on said river to the line of the state of Maine; thence southerly by the line of the state of Maine to a point distant twelve miles in a right angular line from the line last aforesaid; thence in a line as nearly as possible at right angles with the main course of Connecticut river aforesaid, and parallel with the second line above described, to the Connecticut river at the place of beginning."

If these acts are to be interpreted strictly, there is an irregular piece of land between the two grants which has never been assigned to either party. I have given the line as it is usually understood by the lumbermen.

Carlisle's grant is divided into the three townships of Carlisle, Webster, and Hubbard, by the proprietors. As these names appear upon the tax-list of Pittsburg, they are placed upon the map, though they have never been sanctioned by the legislature.

Our experience in matching together the townships in the northern part of the state makes it clear that all the tracts of land there are larger than the bounds assigned to them upon paper. After conference with engineers and map-makers, I find it to be a general rule that land is always larger than the original surveys allow it to be. Astronomers allow a "personal equation" in their calculations from original observations; and, for the same reason, terrestrial boundaries require adjustment after their primal measurements.

I might mention other cases where names and boundaries have been adjusted differently from the previous maps, but do not think them of enough consequence to be presented here. They all show how desirable it would be to have a new map prepared having all its minutiæ settled by competent authority.

CHAPTER X.

ALTITUDES.

IF one would fashion a correct model of New Hampshire, he must first ascertain the exact elevation of numerous points above the ocean. As this has been our constant purpose from the very first, altitudes have been collected by a study of canal and railroad surveys; measurements have been made with mercurial and aneroid barometers; and numerous profiles have been obtained by careful levelling. A multitude of observations have been collected, and it is the object of this chapter to explain how they have been obtained, and to classify them under various headings, such as may be convenient for future reference. If any of our estimates are incorrect, the means of discovering the error will here be afforded.

The delineation of the geological sections across the state has been based upon barometrical measurement, which could be obtained with little additional trouble, at the same time with the examination of strata and the collection of specimens of rocks. This method is, however, subject to inaccuracies, owing to sudden fluctuations in barometrical pressure, and other causes. The most reliable manner of obtaining extended series of altitudes over a large area, so as to arrive with accuracy at the contour or relative height and configuration of its whole extent, is to combine this inexpensive barometrical work, carried in numerous sections across the state, with transverse series of altitudes carefully obtained with an

engineer's level. These being employed as starting-points for comparatively short series of barometrical levels, the latter will be perfectly reliable, so far as regards the accurate construction of profiles across the state, or the delineation of contour lines on a map. For these transverse series, railroad profiles have been employed whenever attainable, together with surveys for canals, water-works, &c., gaps in series being filled up, and a large amount of necessary extensions made. As part of this work, it will be seen that a continuous series of actual levelling has been performed under the direction of the geological survey along our entire western boundary from Massachusetts to Connecticut lake.

Exact information upon this subject, now for the first time obtained throughout the entire extent of New Hampshire, as here given in tabular form, and as presented to the eye in the profiles of geological sections in the state museum, and which it is intended to put in a still more practical shape in a raised map of New Hampshire, may be said to be in many respects of not less importance than a correct outline of the boundaries of the state, with its division into counties and townships. It will be readily seen that knowledge of this kind is almost indispensable to the geologist. Beyond this, when considered in connection with geological structure and proximity to the sea, the relative elevation of any area is the determining feature upon which depend the character of its climate, its agricultural products, its forest trees, the amount and location of its water-power, the facilities for communication, and the consequent distribution of population and wealth.

The different series of altitudes measured by actual levelling are first given, nearly all of which are put in heavy type to indicate their superior reliability, having been proved correct by the agreement of results obtained along different routes. In the lists of altitudes which follow these, the same heavy type designates such points as belong to these series, or have otherwise been exactly determined. Altitudes given in ordinary type have been obtained either from levelling,—where some discrepancy when connected with more carefully determined series prevents a confidence in their entire correctness,—or, as in the sections across the state, from barometrical measurement;—all of these are to be regarded as closely approximate.

This method of printing, and the particular description of the way in

which these altitudes have been determined, with our reasons for decision in cases of disagreement, will enable those who have occasion to use our figures to do so understandingly.

In accordance with the example of eminent physicists, the standard to which all our altitudes are referred is the level of the sea at mean tide. Heights along railroads, unless otherwise specified, are taken on top of the rail in front of passenger stations.

Reference Line from Portsmouth, through Concord and White River Junction, to Connecticut Lake.

Several prominent lines of reference have been determined, which have served as a basis for aneroid measurements and estimates. The first commenced with mean tide water at Great bay, below the railroad bridge between Newmarket Junction and Stratham, May 2, 1870. Messrs. Frank and H. D. Woodbridge, then members of Dartmouth college, levelled from here to Manchester depot, over the Concord & Portsmouth Railroad. They found the mean tide water to be 10.7 feet below the bottom of the rail. The centre of Manchester depot they found to be 180.832 feet above this mean tide water.

The difference between Manchester and Concord depots was derived from a comparison of several measurements, as follows:

Between Manchester depot and Hooksett bridge, ...	24.565
Hooksett bridge to Carter's bridge, Concord (J. A. Weston), . .	40.
Carter's bridge to Concord depot (railroad survey), ...	7.
	71.565

This places the height of track at Concord depot 252.397 feet above mean tide,—16 feet higher than previously supposed. The correctness of this change will appear by the comparison of levels from this base over the Northern and Concord & Claremont railroads, with lines of levels from the sea by way of the Fitchburg and Cheshire railroads, and the recent surveys for the Portland & Ogdensburg Railroad. A strong confirmation of this is further supplied by the Concord & Rochester Railroad survey, by Chas. C. Lund, hereafter given, the profiles of which agree exactly with the corrected height of Concord.

Next, the very accurate surveys of the Northern Railroad between Concord and White River Junction, made by A. M. Shaw, were accepted as correct, the difference between the extremes of the road being 116.840 feet. The height of track at White River Junction is thus placed at 369.237. The accuracy of these levels between Concord and White River Junction is confirmed by the levels of R. S. Howe, engineer of the Concord & Claremont Railroad, which differ from those over the Northern Railroad by only a small fraction of a foot.

To obtain the remainder of this base line, recourse was had to a special survey under A. F. Reed, in 1871, assisted by Dr. N. Barrows of Meriden, and Messrs. C. F. and F. A. Bradley of Dartmouth college. This series extends over the Connecticut & Passumpsic Railroad to Barnet, Vt., at which point it leaves the railroad, and follows the carriage-road to Connecticut lake.

A line of levels from the sea, connecting with this series at Dalton, is furnished by the very reliable surveys for the Portland & Ogdensburg Railroad, crossing New Hampshire through the heart of the White Mountains. The connection between these series was made for the geological survey by James T. Woodbury, in February, 1874, the levels of the Portland & Ogdensburg Railroad survey being found 5 feet higher than those of our series along the Connecticut river. This disagreement has been in part reconciled by adding one half the difference, viz., 2½ feet, to our former figures beyond Dalton to Connecticut lake.

Another series of levels, coincident with the Connecticut river line from Groveton to North Stratford, is supplied from the surveys for the Grand Trunk Railway. These heights were given as referred to tide at Three Rivers, P. Q. To make them agree with our series when changed as just mentioned, it is necessary to call tide at Three Rivers 30 feet above mean sea level,—which is quite near the truth,—tide being stated by Prof. Elias Loomis to be 9 feet at the mouth of the St. Lawrence, and 20 feet at Quebec, while it is probably considerably higher at Three Rivers. Heights along this railroad have been accordingly referred to mean sea level by connecting them with our first series.

With the modification mentioned, Mr. Reed's levels gave the difference between the Junction and Connecticut lake 1,249.626 feet,—the height of the lake being 1,618.863 feet above mean tide.

Summarized, the altitudes are these:

	Difference.	Altitude.
Newmarket Junction,		51.916
Manchester,	+138.916	180.832
Concord,	+71.565	252.397
White River Junction,	+116.840	369.237
Connecticut lake,	+1249.626	1618.863

From South Ashburnham, Mass., through Bellows Falls, to White River Junction.

A second reference line, connecting with the one already described at White River Junction, was obtained from Boston by way of Fitchburg and South Ashburnham, Mass. The height of the railroad at the latter place, as determined by the Fitchburg and Cheshire Railroad surveys, was obtained from the records of the Cheshire Railroad; and the profile of that road was used to Bellows Falls, through the kindness of R. Stewart, superintendent. From this place the remaining distance to White River Junction was levelled over for the geological survey by Warren Upham, assisted by Benj. P. Kelley, in February, 1874. The height of White River Junction thus obtained was 3½ feet above that from the former series. In the list of altitudes upon this series, all heights, from White River Junction to Troy inclusive, are given to agree with the previously determined height of White River Junction, while those south of this point agree with the assumed height of South Ashburnham,—this arrangement being adopted because of a slight discrepancy, amounting to nearly this correction, found to exist at that point in the Cheshire Railroad profile. With the change which would be justified by a more favorable interpretation of the profile at this place, the series from South Ashburnham gives White River Junction 1½ feet higher than by the series from Concord. Another survey over part of this route, in March, 1874, by R. S. Howe, to connect his levels from Concord, over the Concord & Claremont Railroad, with those from the same place over the Northern Railroad, proves by almost exact agreement the entire correctness of this work north from Claremont Junction.

Levels had been already obtained, under the direction of the geological survey, from South Vernon to Bellows Falls, by Gyles Merrill, Jr., in February, 1873, and the completion of this work to White River Junction

gave an unbroken series, wholly from levelling specially for this survey along the entire course of the Connecticut river in New Hampshire.

Summary of the work connected with this series is as follows:

	Difference.	Altitude.
South Ashburnham Junction,		1014.00
Keene,	—535.42	478.58
Bellows Falls,	—174.00	304.58
South Vernon Junction,		261.36
Brattleborough,	—32.95	228.41
Bellows Falls,	+76.17	304.58
Charlestown,	+70.88	375.46
Claremont Junction,	+98.05	473.51
Windsor,	—142.31	331.20
White River Junction,	+38.03	369.23

The altitudes comprised in these two reference lines are arranged in full under Nos. 1, 2, and 3 in the tables of this chapter. The last of these contains the heights determined along Connecticut river, the reliability of which is attested by the close agreement of four series directly from the sea, viz., through South Ashburnham, through Concord, and by way of the Portland & Ogdensburg Railroad and the Grand Trunk Railway.

From Boston, by way of Boston & Maine, Portsmouth, Great Falls & Conway, and Portland & Ogdensburg Railroads, to Dalton.

A third reference line, extending along the eastern portion of the state, and connecting with the Connecticut river series at Dalton, has been obtained entirely from railroad surveys. These altitudes from Boston to Great Falls were taken from the original profile of the Boston & Maine Railroad, through the kindness of Pres. White, at his office in Boston. On this profile, reference was to marsh level (high tide), and 5 feet have been added to the figures there given for height above mean tide. These figures show an exact agreement at Newmarket Junction with the series measured by the Messrs. Woodbridge, and again at Great Falls with the altitudes furnished by T. Willis Pratt, engineer of the Portsmouth, Great Falls & Conway Railroad, from mean tide at Portsmouth. By this latter series the line is continued to North Conway. The levels for the Wolfeborough Branch, including the altitude of Lake Winnipiseogee, were furnished by George L. Whitehouse, Esq., of Farmington, and

by J. W. Lovering, assistant engineer. At North Conway, this series connects with that of the Portland & Ogdensburg Railroad, with which it closely agrees; and the remainder of this line, which here turns northwesterly, has been supplied by John F. Anderson, chief engineer, from the surveys of that railroad, now being built through the White Mountain notch. The whole line of this road is given from Portland, and, as the reference of these surveys was to mean low water in Casco bay, as established by engineers of the U. S. C. S., 4 feet have been subtracted from the heights of their profile given in our annual report for the year 1871, to reduce to mean tide. The connection between this series at Dalton and the line along Connecticut river has been already mentioned. It will thus be seen that the accuracy of this reference line is confirmed by a close agreement of altitudes, obtained by five different courses of direct levelling from the sea.

A summary of prominent points along this line is as follows:

	Difference.	Altitude.
South Lawrence, Mass., depot,		49
Exeter,	+9	58
Dover,	+14	72
Great Falls,	+106	178
Rochester,	+48	226
Lake Winnipiseogee, low to high water,		496–502
North Conway, P., Gt. F. & C. Railroad depot,		516
White Mountain notch, railroad summit, 1893; surface,		1914
Connecticut river, one fourth mile below mouth of John's river, at head of Fifteen-mile falls,—low to high water,		827.6–832

Additional Railroad Surveys.

Many other extended series of altitudes have been determined by the various railroad surveys throughout the state, and wherever these have been preserved and are still attainable, they have been secured, and are presented in the tables following those of the special reference lines along our east and west borders already described. In some instances, however, these records, from various causes, have been unfortunately lost. On this account it was found necessary, in establishing our western reference line, to level along our whole western boundary, although railroad lines extend over three fourths of this distance, and were adopted

for our work as affording the easiest route. For the same reason it will be seen that we have failed to present complete lists of heights along some other railroads, while in a few cases no records whatever could be obtained.

Among the railroad lines which we are able to present are,—a survey between Exeter and Salisbury, Mass.; the recent surveys for the Nashua & Rochester Railroad, with points on a survey from Windham, the junction of this road with the Manchester & Lawrence Railroad, to Lowell; various points along the Boston, Lowell & Nashua, Wilton, and Peterborough railroads, with additional surveys extended from the present terminus at Greenfield to the Connecticut river near Charlestown, and a few points on a survey for this road from Claremont village to White River Junction; a series of heights determined by surveys between Rochester and Concord; the Suncook Valley Railroad; points on the Manchester & North Weare Railroad, and others determined by surveys extended westward to Keene; the very accurate surveys of the Concord & Claremont Railroad, with the Hillsborough Branch; and the Boston, Concord & Montreal Railroad. These various surveys have been tabularly arranged in the above order, exhibiting several accurately measured transverse sections of the state, while, by the last, a longitudinal series is furnished from Lake Winnipiseogee to Lancaster. Other altitudes have been gathered from railroad surveys not here mentioned. In all cases the name of the surveyor, or the source from which information has been obtained, is given, with any explanation which could add to its practical value.

Miscellaneous Altitudes.

Other accurately determined altitudes have been collected from different sources. A considerable number of these, in the vicinity of our cities, are from the surveys for water-works. Others are from surveys for canals, or for manufacturing companies, by which heights along the rivers have been obtained, with the amount and extent of many of the most important falls. Where such information has not been attainable, the height of our largest rivers has been stated approximately. These altitudes are not presented here in full, as they would to a large extent require repetition in another chapter, treating of our water-power.

They will be found there, arranged in the description of river systems, together with heights of the principal lakes and ponds of the state, and others along lines of water-sheds, many of which, taken from barometrical measurement, are not to be regarded as exact.

The altitudes of principal points along the main water-shed of New Hampshire, separating the waters of the Connecticut from those of the Androscoggin, Saco, and Merrimack, being of the first importance as illustrating the topography of the state, have been already given in a preceding chapter. Also, in the same chapter, are to be found heights along the boundaries of New Hampshire.

The lists of altitudes of villages, of some of the largest lakes and ponds, of the largest rivers at a few places, and of other points of interest throughout the state, have been derived from various sources, the degree of probable accuracy being indicated by the difference in type.

The table of heights of the mountains and principal hills of the state, with miscellaneous points in the mountain region, comes, to a large extent, from barometrical measurement. Others, both in this list and in that of villages, &c., have been copied from different publications, in which case the original authority is usually given, exact measurements being distinguished by heavy type. A very valuable list of altitudes, principally of mountains and hills, has been obtained, in connection with the triangulation of the state under the U. S. Coast Survey, by Prof. E. T. Quimby; these, so far as the survey has been already extended, are given on p. 242.

Geological Sections.

Fourteen general sections have been measured, extending across the state in parallel lines, nearly east and west. Their geological character will be given subsequently; but it is the proper place here to state what figures have been used in drawing their profiles, as exhibited in connection with the rock specimens in the state museum at Hanover. Exact determination by levelling has been secured for the starting-point wherever practicable, and the aneroid barometer has been employed for determining heights beyond. The details cannot very well be presented with each determination, as they are too voluminous, and not of great consequence.

The names of residents, streams, hills, and mountains are taken from


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the several county maps. Exceptions to this rule may occur. Our intention is to have the names conform to those adopted upon our geological map. The most important deviations from the usage of the county maps have been explained in Chapter IX.

The results of the numerous railroad and special surveys here exhibited, together make up a complete network of interlocking series of accurately determined altitudes throughout the entire state. With this as a basis of reference, it is believed that the barometrical measurements of the altitudes of villages and of general sections will be found of the highest value, in an inquiry into the geology, climate, and physical character of New Hampshire.

TABLES OF ALTITUDES.

1. Portsmouth to White River Junction.

Heights along the Concord & Portsmouth Railroad. Levelled by Frank and H. D. Woodbridge, in 1870, for the geological survey. Altitudes are given above mean tide in Great bay; distances are given from Portsmouth.

	Distances in miles.	Heights in feet.
Newmarket Junction,	10	51.916
Littlefield's Crossing,		126.053
Epping,	18	154.147
Raymond,	23	197.881
Candia,	29	445.190
Manchester, centre of depot,	41	180.832
Top of dam at Manchester,		178.980
Amoskeag base line,		108.980

Surveys used in the Construction of the Road. From original profiles.

Piscasset river (water level), S. Newmarket, 72; track,	77.
Lamprey river (water level),	141.
Same at Raymond,	173.
Outlet of Jones pond (water level),	258.
Road at Patten's shingle mill, Candia,	373.
Level of ground " " "	354.
Brook east of Candia depot (water level),	410.
Cass's Crossing, Candia,	485.
Summit at Kinnecum's swamp, abandoned route,	528.
Turnpike at Rowe's Corner, " "	453.

	Distances in miles.	Heights in feet.
Summit in Candia on railroad after construction to Manchester,		465.
Auburn depot, ...	33	289.
Massabesic pond, ...	36	256.
Summit between Massabesic and Merrimack river at J. P. Eaton's,		344.

By another Route.

Bean's island, Candia, ...	275.
Lamprey river, Candia Village, ...	301.
Highway in Candia Village, ...	310.
Summit towards Allenstown, ...	550.

A Survey through Deerfield.

Quincy pond, Nottingham, ...	288.
Summit between Quincy pond and Lamprey river, ...	406.
Summit, ...	576.
Suncook river, Buck street, ...	259.
Suncook Village, ...	281.

Beyond Manchester the results of different surveys have been connected to obtain the height of Concord, as follows:

	Heigbts in feet.
Martin's Ferry, ...	198.92
Hooksett bridge,* . . . . , .	205.397
Carter's bridge, Concord (J. A. Weston), ...	245.397
Concord, centre of depot, 59 miles from Portsmouth (Railroad survey),	252.397

Heights along Northern Railroad. From original surveys, by A. M. Shaw, engineer.

	Distances from Concord.	Heights in feet.
Concord, 75 miles from Boston, ...		252.39
Fisherville bridge, ...	7 miles.	267.89
Boscawen, ...	10 "	273.89
North Boscawen, ...	14 "	290.01
Webster Place, ...	17 "	295.26
Franklin, ...	19 "	363.26
East Andover, ...	25 "	661.
Andover, ...	29 "	628.
Potter Place, ...	31 "	653.
West Andover, ...	32 "	677.

* Derived from Hobbs's levelling from Amoskeag base line to foundation of north abutment, 180.197 feet. Rail is twenty-five feet higher by tape-line measurement.

	Distances from Concord.	Heights in feet.
South Danbury,	35 miles.	732.
Danbury,	38 "	826.
Grafton,	43 "	848.
Grafton Centre,	44 "	871.65
Tewksbury pond,		904.
Orange summit,		990.
Railroad at Mud pond,		957.
Canaan,	51 "	956.
West Canaan,	55 "	813.
Enfield,	58 "	768.34
East Lebanon,	60 "	765.63
Lebanon,	64 "	510.31
West Lebanon,	69 "	376.13
Bridge over Connecticut river,		376.13
Connecticut river, high water,		352.84
Connecticut river, low water,		330.07
White River Junction,	69 "	369.23

2. Heights along the Cheshire Railroad.

Copied from original profile, through kindness of R. Stewart, superintendent.

	Distances from South Ashburnham.	Heights in feet.
South Ashburnham Junction, 61 miles from Boston; altitude obtained via Fitchburg and Cheshire Railroad surveys,		1014.
Ashburnham summit,	1.5 miles.	1084.
North Ashburnham,	3.3 "	1066.
Railroad bridge over Miller's river, near line between Ashburnham and Winchendon,	4. "	1037.
Miller's river—track, 990; water,	6. "	973.
Winchendon,	7.8 "	992.
Winchendon summit,	8.5 "	1018.
State line station,	10.9 "	898.
Lowest point (level),	11.–11.5 "	893.
Mill-pond, water,	13.2 "	956.
Collins pond—track, 1067; water,	15.9 "	1062.
Fitzwilliam,	16.2 "	1063.
Fitzwilliam summit,	18.4 "	1151.
Rockwood pond, water,	19.1 "	1112.
Troy,	21.5 "	1002.

	Distances from South Ashburnham.		Heights in feet.
Gulf bridge, track,	23.9	miles.	871.
Marlborough,	25.3	"	789.
South Keene,	29.3	"	560.
Arch bridge over Branch river—track, 551; water,	29.4	"	507.
Keene (1½ miles' level),	31.3	"	479.
Ashuelot river, water,	31.9	"	469.
Ash Swamp brook—track, 530; water,	33.2	"	487.
Surry summit,	38.3	"	830.
East Westmoreland,	40.4	"	709.
Westmoreland,	43.7	"	512.
Walpole,	49.8	"	277.
Lowest point of railroad between South Ashburnham and Bellows Falls, level,	50.3–51.	"	255.
Cold river, water,	52.3	"	232.
Cold River station,	52.6	"	259.
Connecticut River railroad bridge,	53.6	"	304.
Bellows Falls,	53.7	"	304.58

3. Western Line of Reference.

ALTITUDES ALONG CONNECTICUT RIVER, FROM LEVELLING FOR THE GEOLOGICAL SURVEY.

South Vernon to Bellows Falls. Levelled by Gyles Merrill, Jr., in February, 1873, following Vermont & Massachusetts and Vermont Valley railroads.

	Distances from Bellows Falls.		Heights in feet.
South Vernon,	33.9	miles.	261.360
Brattleborough,	23.7	"	228.411
Road to village, at crossing,	23.4	"	231.456
West River railroad bridge,	22.3	"	244.151
Railroad bridge over highway,	19.7	"	271.016
Dummerston,	18.2	"	262.535
Salmon Brook railroad bridge,	17.0	"	238.635
Bridge at "Hollow,"	16.2	"	239.935
Putney,	14.7	"	257.317
Sackett's Brook bridge,	14.3	"	262.252
East Putney,	11.7	"	295.542
Barney's Brook bridge,	7.1	"	253.053
Grout's crossing,	5.4	"	258.633
Westminster,	3.7	"	264.285

	Distances from Bellows Falls.	Heights in feet.
Governor's Brook bridge,	3.1 miles.	257.284
Saxton's River bridge,	.9 "	272.358
Bellows Falls depot,		304.580
Top of stone abutment at south end of Sullivan Railroad bridge,		304.010

Bellows Falls to White River Junction. Levelled by Warren Upham, in February, 1874, following Sullivan and Central Vermont railroads.

	Distances from South Ashburnham.	Heights in feet.
Bellows Falls Junction, 115 miles from Boston,	54 miles.	304.58
Connecticut river below the falls,		234.01
Connecticut river above the falls,		283.34
"Dutchman's crossing," about 1 mile north of Bellows Falls,		330.16
Summit about ½ mile farther north,		340.69
Hooper's crossing, ⅝ mile south of South Charlestown,		310.61
South Charlestown station,	58 miles.	302.30
Kendall's crossing, ⅜ mile north So. Charlestown stat'n,		302.70
Lowest point on railroad near this place,		301.38
Evans's south crossing,		335.30
Evans's north crossing,		336.90
Railroad bridge over road south of Charlestown, known as "Dry bridge,"		350.46
Charlestown station,	62 miles.	375.46
Crossing, about 1 mile north of Charlestown station,		372.19
Summit at Springfield (Vt.) station,	65 miles.	374.40
Lowest point of railroad in Beaver meadow,		313.79
Gowing's crossing, ½ mile south of North Charlestown,		402.75
North Charlestown station,	68 miles.	416.08
First crossing north of North Charlestown station,		426.14
Merrill's crossing, second north of North Charlestown station,		445.82
Summit near Mr. Long's, about 1⅝ miles south of Claremont Junction,		468.98
Claremont Junction,	72 miles.	473.51
Summit about ¼ mile north of Claremont Junction,		478.16
Railroad under Ellis's bridge,		463.26
Jarvis's bridge (railroad over highway),		428.98
High bridge over Sugar river (centre),		405.78
West Claremont station,	74 miles.	404.28

	Distances from South Ashburnham.	Heights in feet.
"Punkshire" Road crossing, ¾ mile north-east from Ascutneyville, Vt.,		366.65
Balloch's crossing, in south edge of Cornish,		368.37
Connecticut river, about 1 mile south of Chase's island,		302.12
Railroad in front of Mr. Chadborn's,—birthplace of Chief Justice Chase,		366.01
Windsor Railroad bridge (centre),		351.81
Bridge over Mill brook,		340.70
Windsor station,	80 miles.	331.20
Bridge over Lull's brook,		398.98
Hartland station,	84 miles.	421.01
Summit, about 1½ miles north of Hartland,		464.58
Railroad under highway bridge, ½ mile north,		444.84
Crossing about 1⅝ miles south of North Hartland,		421.75
North Hartland station,	88 miles.	387.90
Bridge over Quechee river (centre),		370.39
Connecticut river here (above Sumner's falls),		323.04
Crossing about 1¾ miles south of White River Junction,		377.81
White River Junction,	94 miles.	369.23

White River Junction to Connecticut Lake. Levelled by A. F. Reed in 1871, following the Connecticut & Passumpsic and Grand Trunk railroads, and the highway.

	Distances from White River Junction.	Heights in feet.
White River Junction, 144 miles from Boston, 69 miles from Concord,		369.237
Norwich depot,	4 miles.	406.300
South end of bridge over Pompanoosuc river,	10.5 "	409.027
Crossing near Mr. Blood's, Norwich, minimum grade,		395.064
Crossing 1¼ miles south of East Thetford,		410.145
East Thetford depot,	14 "	413.325
North Thetford depot,	16 "	401.741
Crossing 1½ miles north,		420.233
Crossing 2½ miles north,		435.741
Crossing 1½ miles south of Fairlee,		432.781
Fairlee station,	21.5 "	437.952
Water house, railroad, Sawyer's mountain,		449.439
Piermont station,	27 "	439.627
Bradford station,	28 "	410.007
Crossing 2 miles south of Haverhill,		408.912
Chamberlin's crossing,		409.071

	Distances from White River Junction.	Heights in feet.
Hall's brook,		410.027
Haverhill depot,	32 miles.	412.142
Crossing to Newbury bridge over Connecticut river,		413.857
Newbury depot,	35 "	426.002
Wells River depot,	40.2 "	442.898
Crossing 3 miles north,		437.642
Ryegate depot, platform,	44 "	471.710
Crossing 1 mile south of McIndoe's,		494.895
McIndoe's depot,	48.2 "	487.913
Barnet depot, last point measured on the railroad,	50.7 "	467.114
Hay scales, Upper Waterford,	61 "	752.368
Bridge, Upper Waterford, 15 feet above water,		689.046
Piazza, Sumner house, Dalton,	73 "	898.153
Top of stone hitching post, south end of Dalton post-office,		912.608
Door of County house, Lancaster,	80 "	867.444
Hay scales, Northumberland,	85 "	865.352
Bridge over Upper Ammonoosuc river, Groveton,		882.670
Groveton depot (Grand Trunk Railway),	89 "	900.910
Railroad bridge 2 miles above Groveton,		905.633
Stratford Hollow depot,	93.5 "	877.388
Stratford, flag station,		880.242
North Stratford station,	101 "	915.184
Columbia bridge,	109 "	1011.268
Colebrook bridge,	113 "	1025.674
Middle of window on school-house 5 m. north of Colebrook,		1078.784
East end of Canaan bridge over Connecticut river,	120 "	1053.699
Bridge over Hall's stream,	121.5 "	1097.963
Foundation of red school-house at the "Hollow," 6 miles from Connecticut lake,		1494.970
Connecticut lake,	134 "	1618.606

4. Eastern Line of Reference.

Heights along Boston & Maine Railroad. Copied from original profile, through kindness of N. G. White, president, and reduced to mean tide.

	Distances from Boston.	Heights in feet.
Station at Boston,		13.5
Melrose, Mass.,	7. miles.	62.
Wilmington Junction, Mass.,	18.1 "	88.
South Lawrence, Mass.,	26. "	49.

	Distances from Boston.	Heights in feet.
Haverhill, Mass.,	33.2 miles.	33.
Atkinson,	36.7 "	57.
Plaistow, brickyard,	37.6 "	86.
Plaistow,	38.5 "	92.
Newton,	41. "	125.5
Newton, railroad summit,	42.2 "	142.
East Kingston,	45.8 "	130.
Bridge over Exeter river,	49. "	41.5
Exeter,	50.4 "	58.
South Newmarket,	54.7 "	38.
Newmarket Junction,	55.7 "	52.
Newmarket,	57.5 "	40.
Bridge over Lamprey river (track),	59.3 "	48.
Bridge over Durham river (track),	61.4 "	74.
Durham,	61.9 "	70.
Railroad summit near Madbury,	63.8 "	118.
Madbury,	64.3 "	108.
Bridge over Cochecho river (track),	67.3 "	67.
Dover,	67.6 "	72.
Rollinsford,	70.3 "	115.
Railroad summit near Rollinsford,	71. "	127.
Salmon Falls,	71.6 "	107.
Great Falls (branch of B. & M. R.),	73. "	178.
Summit between Alton and Farmington (branch of B. & M. R. R.),		571.

Heights along Portsmouth, Great Falls & Conway Railroad. Furnished by T. Willis Pratt, engineer.

	Distances from Portsmouth.	Heights in feet.
Kittery, Me.,	1 mile.	17
Elliot, Me.,	7 miles.	21
Great Falls (Conway) Junction,	11 "	90
Great Falls station, about 12 feet higher than dam,	16.5 "	178
Rochester station, on level plain,	23 "	226
Milton station, about 6 feet higher than Three Ponds,	31 "	415
Wakefield station (railroad summit), about 10 feet lower than the village street,	42.5 "	690
East Wakefield (railroad summit),	46.2 "	678
Ossipee, ¼ mile from village,	54.3 "	642
Summit, ¼ mile farther on,	54.5 "	654
West Ossipee, on flat land in vicinity of Ossipee lake, and near the hotel, perhaps 20 feet higher than lake 3 miles off,	64.7 "	428

	Distances from Portsmouth.	Heights in feet.
Madison, north-west end of Six-mile pond (Silver lake),	69.5 "	476
Summit 2 miles beyond,	71.3 "	516
Conway Corner (Chateaugay), west end of village,	76.6 "	466
Crossing Saco river, summer level,	80 "	446
North Conway station,	82 "	516
Jackson, on the road between the two bridges,	90 "	759

Wolfeborough Branch. Furnished by J. W. Lovering, assistant engineer.

	Heights in feet.
Wolfeborough Junction, 49.5 miles from Portsmouth,	574
Railroad summit east of Cottonborough station,	664
Lake Winnipiseogee, surface of water, October, 1871,	500.5
" " " " March 26, 1872,	498.26

Heights along the Portland & Ogdensburgh Railroad. Furnished by John F. Anderson, engineer, and reduced to mean tide. Initial point of distances at the west end of P. & K. Railroad Company's freight house, in Portland, Me.

Localities in Maine.

	Distances in miles.	Heights in feet.
Surface of Presumscot river, on ice,	5.64	39
Surface of Presumscot river, on ice,	13	130
Surface of Sebago lake, on ice,	17	263
Steep Falls of the Saco river (village),	24.5	305
Surface of the Saco river, at mouth of the Ossipee,	32	266
Surface of Ingalls pond, near head of Great Falls, Saco river,	35.4	350
Fryeburg station, natural surface of plain,	49.7	420
Highway at state line, Maine and New Hampshire,	51	451

Localities in New Hampshire.

Saco river at railroad crossing, Conway Centre,	55.25	412
Surface of North Conway village, terrace plain,	60	521
Saco river at junction of the Ellis river,	64.5	511
Saco river at junction of the Rocky Branch,	66	560
Surface of plain of Upper Bartlett village,	70.5	660
Saco river at line between Bartlett and Hart's Location,	72.5	745
Surface of Sawyer's river at highway bridge,	74.2	863
Surface of Nancy's brook at highway bridge,	76.2	1003
Highway at Willey house,	82.2	1323
South end of gate of notch,	84.3	1819
Crawford house,	85	1899
Highest grade near Crawford house,		1893

	Distances in miles.	Heights in feet.
Surface of ground at the lowest point of water-shed between the Saco and Ammonoosuc,		1914.
Head waters of Saco river, a small pond, 1300 feet south-east from Crawford house,		1880
Fabyan house,	89	1571
Ammonoosuc river, 250 feet east of Fabyan house,		1559
Same, 1200 feet east of White Mountain house,		1545
White Mountain house,	90	1556
The slope of the interval here is about 12 feet in a mile.		
High water in Ammonoosuc river above Leavitt & Nason's mill, "Lower falls,"	90.5	1543
Pool below "Lower falls,"		1503
Twin Mountain station,	93.8	1446
Twin Mountain house,		1429
Whitefield station,	103.5	948
Crossing of B., C. & M. Railroad,	106.5	882
Connecticut river, Dalton, high water,*.		832.06
Connecticut river, at head of Fifteen-mile falls, low water,		827.68

5. Railroad Surveys in Southern New Hampshire.

Heights between Epping and Salisbury, Mass. From surveys for the Exeter & Salisbury Railroad, furnished by J. J. Bell, Esq., of Exeter.

	Heights in feet.
Epping depot,	154
Junction with C. & P. R., 5,000 feet east of depot,	144
Piscasset river, at crossing,	119
Crossing road to Marshall's corner,	122
Little or Deerhill river, at highest crossing,	62
Little or Deerhill river, at second crossing,	31
B. & M. R., at Exeter depot,	58
Exeter dams,	18.97
Rockingham factory dam,	34.29
Little river, at lowest crossing, and Exeter river,	22
High water in Exeter river,	27.5
Grassy meadow,	25
Old road to Newburyport, near Kensington line,	42
Old road north of Brown's,	68
North road, Kensington, near J. Fellows's,	56
North road, at Tuck's tannery,	75
Poor's mill-pond, high water,	114

* Incorrectly stated on page 177.

	Heights in feet.
Kingston road, a little above D. Merrill's,	51
Hampton Falls river, below Weare's mill,	41
Hampton Falls river, above Weare's mill,	63
Evans's mill-pond,	50
Eastern Railroad, a little below Salisbury depot,	28

Heights along Nashua & Rochester Railroad. Furnished by C. O. Davis, engineer, from profile of the road, which shows agreement with previously determined altitudes at Nashua, Epping, and Rochester. Rivers and ponds are given at their actual height at the time of survey. Distances are from the junction with the Worcester & Nashua Railroad at Nashua.

	Distances in miles.	Heights in feet.
Merrimack river, low to high water,	.6	91–115
Bridge over Merrimack river,		126
Crossing near Dr. Smith's, Hudson Centre,	2.6	203
Hudson summit, near Mr. Clement's,	3.8	262
Beaver brook (water), line between Hudson and Windham,	5.3	172
Windham summit,	9.8	345
Windham station, crossing M. & L. R.,	10.3	324
Hampstead station,	16.5	258
Exeter river, outlet of Phillips pond, Sandown,	18.4	215
Exeter river, second crossing, Sandown,	20.6	176
Exeter river, third crossing, Danville,	21.6	175
Exeter river, fourth crossing, below Scribner's mills, Frěmont,	23.4	135
Spruce swamp,	25	161
Epping crossing, C. & P. R.,	28.2	154
Pawtuckaway river,	28.6	103
North river, Epping,	32	95
Little river, Lee,	34.9	118
Wheelwright's pond, Lee,	36.4	131
Crossing, Concord & Portsmouth turnpike,	37.4	153
Newton plain, Lee,	38	198
Bellamy river,	39.7	148
Winkley's pond, Barrington,	40.4	167
Malagar river,	41.1	154
Summit, at Barrington station,	41.9	207
Isinglass river,	44.9	158
Gonic summit,	46.6	201
Cochecho river,	46.9	173
Rochester,	48.3	226

Heights between Windham and Lowell. From a preliminary railroad survey, by Charles C. Lund, of Concord.

	Heights in feet.
Windham, junction of M. & L. and N. & R. railroads,	324
Windham Centre,	244
Neal's mill-pond, Windham,	176
Pelham village,	134
Beaver brook at this place,	126
High terrace of the Merrimack at mouth of Beaver brook,	118
Water in river here,	57

Heights along Boston, Lowell & Nashua, and Nashua, Wilton & Peterborough railroads, and proposed extensions. Furnished by M. W. Oliver, engineer, and reduced to mean tide.

	Distances from Boston.	Heights in feet.
Passenger station, Boston,		11
Winchester, Mass.,	8 miles.	27.10
East Woburn, Mass.,	10 "	33.30
Lowell, Mass.,	26 "	99.11
North Chelmsford, Mass.,	29 "	106
Switch to Concord Railroad,	39 "	122.41
Nashua,	39.5 "	134.51
East Wilton,	55 "	328
Near hotel in Greenfield,	65 "	835
Contoocook river, on Forest road between Greenfield and Hancock,		640
Hancock street, between church and academy,		826
Water in Hancock pond,		792
Rye pond, south-west corner of Antrim,		1235
Bridge on the Keene and Concord road, east of "Box tavern," Stoddard,		1223
Upper or principal Island pond, Stoddard,		1248
Summit north of Wilson's,		1560
Junction of Forest and Keene roads, near Marlow,		1188
Pond at Marlow,		1123
Junction of Old and New Forest roads,		1333
Gustin pond,		1250
Forest Road bridge over Cold river,		619
Sills of Universalist meeting-house, Paper Mill Village,		475
Spofford's gap, between Temple and Kidder mountains in Temple,		1465
Hedgehog gap, probably between Temple and Pack Monadnoc mountains in Temple,		1457

	Heights in feet.
Arlington, Mass.,	41
Lexington common, Mass.,	222
Bedford, Mass.,	175
Railroad at Greenville,	803
Hay-scales at New Ipswich,	944

Claremont to White River Junction.

Furnished from surveys for Boston, Lowell & Nashua Railroad, by G. B. Pearson, of Nashua.

	Distances from Claremont.	Heights in feet.
Sill of Lyman Barnes's house, Claremont,		528.93
Edminster school-house,	5.1 miles.	908.36
Cornish Flat (proposed station),	9.3 "	854.90
Sill of Bryant's barn,	9.5 "	842.49
Bridge at Moore's mill, Plainfield,	13.8 "	837.27
Wood's mill, Lebanon,	18.3 "	462.53
West Lebanon station, N. R. R.,	21.9 "	376.13

6. Railroad Surveys in Central New Hampshire.

Heights between Concord and Rochester. Furnished from surveys for C. & R. Railroad, by Chas. C. Lund, engineer.

	Heights in feet.
Railroad at East Concord,	246
Dark plains, on east side river opposite Concord,	356
Soucook river, 4½ miles from E. Concord,	307
Lynxfield pond, Chichester,	432
Summit in survey, ¾ mile east of Lynxfield pond,	451
Suncook river, ½ mile above Chichester pine ground,	338
Railroad at Epsom,	342
Suncook river, below Lord's mills,	497
Suncook pond, Northwood,	512
Swamp on water-shed,	612
Bow pond, Strafford,	515
Isinglass river, ¾ mile below Bow pond,	482
Nippo river, at crossing 3½ mile from Bow pond,	281
Isinglass river, 5 miles from Bow pond,	233
Railroad at Pittsfield,	493
Blue Hill gap, Strafford,	686
Railroad at Rochester,	226

Heights in Gilmanton and Belmont. Furnished from preliminary railroad surveys, by R. S. Howe, engineer.

	Heights in feet.
Hatch's store, Gilmanton Iron Works,	604
Barnstead road, ½ mile south of this place,	582
First reservoir above this village (Lougee pond),	622
Second reservoir above this village,	615
South gap, Gilmanton,	1102
North gap, Gilmanton,	1088
Factory pond reservoir,	1011
Garmon's mill-pond,	665
Reservoir pond above Belmont village,	602
Sargent's mill-pond, Factory Village,	556

Heights along Suncook Valley Railroad and proposed extension. Furnished by Hon. S. N. Bell, president, from surveys under the direction of Hon. J. A. Weston.

	Distances from Hooksett.	Heights in feet.
Hooksett bridge, 66 miles from Boston,		205
Bridge over Suncook river,	2.4 miles.	243
Highway crossing near Suncook house,		302
Highway crossing near Tennant's saw-mill,		306
Highway crossing, Buck street, Allenstown,	7 "	342
Bear brook (water level),	8 "	294
Highway crossing at Jenness Corner,		338
Mouth of Little Suncook river,	12.5 "	336
Epsom depot,		362
Chichester pine ground, depot,	15 "	373
Highway crossing near Webster's mills,	17 "	409
Pittsfield depot,	19.5 "	493
Suncook river, above dam, Pittsfield,		471
Barnstead Parade,		512
Barnstead Centre,		527
Suncook river, below Gilmanton Iron Works,		582
Suncook river above Gilmanton Iron Works,		603
Gilmanton Iron Works village,		647
Summit between this place and Alton,		852
Water-shed between lake and Cochecho river,		571
Terrace, approx.,		550
Hotel, Alton Bay,		530
Winnipiseogee,		500

Heights on Manchester & North Weare Railroad and proposed extensions. Furnished by Hon. J. A. Weston, engineer, and reduced to mean tide.

	Heights in feet.
Goffstown station,	304.09
Parker's station,	318.69
Piscataquog river at Parker's station, Goffstown,	298.69
Piscataquog river below bridge at New Boston village,	421.83
North Weare,	489
Summit,	537
Town line, Weare and Henniker,	524
Contoocook river, water,	389
Street-crossing, old New Hampshire Central Railroad, Henniker,	455
Former station, New Hampshire Central Railroad, Henniker,	469

Manchester & Keene Railroad, in part.

Piscataquog river below bridge at New Boston village,	421.83
Piscataquog river at west line of New Boston,	514.63
Francestown turnpike, near north-east corner of Lyndeborough,	613.53
Forest road south of Greenfield Centre (summit in railroad survey),	915.69
Meadows between Greenfield and Peterborough, and near Greenfield,	816
Contoocook river, above stone bridge and dam at Peterborough Centre,	734
Meadow on Goose brook, above West Peterborough,	927
Long meadow, on Goose brook in Hillsborough and Dublin,	960
North pond in Harrisville,	1218
Harrisville,	1334
Summit on railroad survey in Harrisville,	1265
Mud pond in Harrisville,	1256
Reservoir at head of "Gulf" in Marlborough,	1137

Monadnock & Peterborough Railroad. From preliminary surveys under the direction of Hon. J. A. Weston.

	Heights in feet.
Peterborough village,	744
Contoocook river above Peterborough,	748
River below Cragin's mill,	809
Town line between Peterborough and Jaffrey,	901
Bacon's mills, Jaffrey,	922
River at Cheshire factory,	977
East Jaffrey,	1032
River above Squantum,	1099
Town line between Jaffrey and Rindge,	1127
Three ponds in north part of Rindge, each,	1114

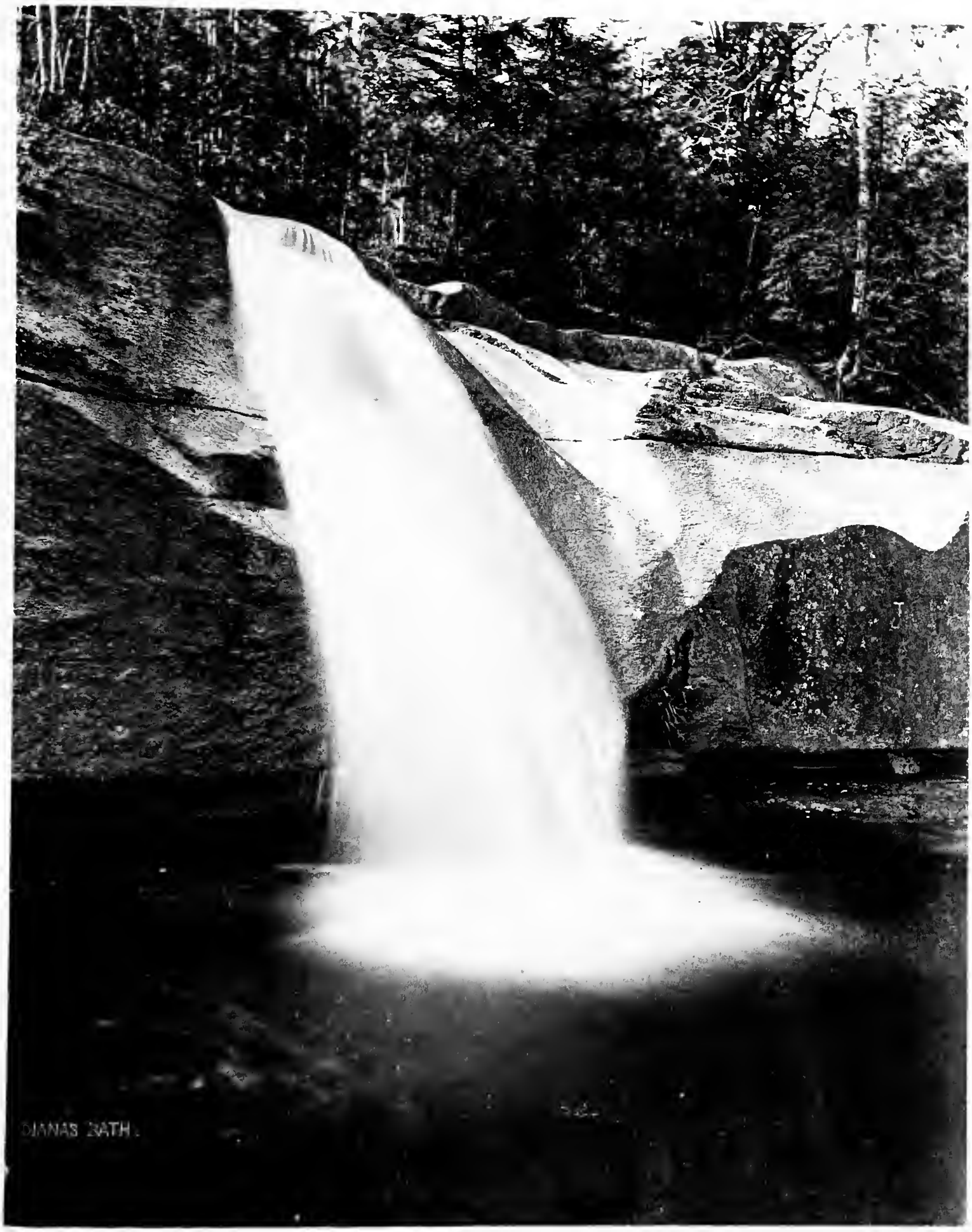
	Heights in feet.
East Rindge,	1003
State line, between Rindge and Winchendon,	1060
Winchendon village (Cheshire Railroad intersection),	992

By another Route from East Jaffrey.

Cemetery, East Jaffrey,	1045
Contoocook river, 3000 feet south from north line of Rindge,	1044
Towne's mill, Rindge,	1031

Heights along the Concord & Claremont Railroad and Hillsborough Branch. Furnished by R. S. Howe, engineer.

	Distances from Concord.	Heights in feet.
Concord—75 miles from Boston; 59 miles from Portsmouth,		252.39
West Concord,	3 miles.	353.69
Summit,	5.6 "	378.42
Mast Yard,	8 "	374.57
Summit,	10.1 "	395.30
Contoocook,	12 "	373.38
Dimond's Corner,	14.5 "	424.98
Pleasant pond, on the south, at this place,		428.10
Tom pond, on the north, at this place,		398.32
Warner,	18.5 miles.	421.82
Sill of Simonds High-school building, Warner,		498.24
Bradford,	27.5 miles.	678.79
Todd pond, near this station,		677.41
Newbury summit (rock-cut), over rail,		1181.07
Newbury summit, on rail,		1130
Lowest point between the Connecticut and Merrimack rivers, about 400 feet south of railroad,		1161.24
Sunapee lake—low water, 1090; high water,		1103.22
Spectacle pond, Sunapee,		1122.73
Mt. Sunapee station,		1128
Sunapee,	40 miles.	955.72
Newport,	43 "	802.32
New court-house, Newport, sill at front door,		822.05
Northville, bridge over Sugar river,	46 miles.	783
Mineral spring above Kelleyville, near railroad,		707.04
Claremont,	54.5 miles.	543.10
Foot of shaft, soldiers' monument, Claremont,		567.47
Claremont Junction,	56.5 miles.	473.25


DIANAS BATH.

Hillsborough Branch Contoocook Valley Railroad.

	Distances from Concord.	Heights in feet.
Contoocook,	12 miles.	373.38
West Hopkinton,	15 "	391.79
Crossing of old N. H. Central Railroad, Henniker,		426.29
Henniker,	20 "	439.32
Paper-mill pond, water,		432.02
Foot of Long fall, Contoocook river,		433.82
Head of Long fall, 10,000 feet distant,		546.91
Hillsborough Bridge station,	27 "	574.03

Heights in Boscawen and Salisbury. Furnished from surveys for Blackwater River Railroad, by R. S. Howe, engineer.

	Heights in feet.
Dingett's Corners,	479.90
Blackwater river at crossing, ⅝ mile above this place,	442.96
Clark's island,	508.80
Blackwater river, ⅛ mile above Clark's island,	526.67
Webster village,	555.00
Salisbury, south line of township,	568.72
South Salisbury, road,	563.2
Salisbury Centre, road,	592.50
North Salisbury, island in river,	602.20
The "Bay" at this place,	598.90
Fourth N. H. Turnpike, near J. G. White's, Andover,	632.00
South-west corner of the town of Salisbury,	899.23

Heights on Kearsarge Mountain. Furnished from carriage-road survey, Warner, by R. S. Howe.

	Heights in feet.
U. S. Signal post, Kearsarge mountain,	2942.79
Kearsarge mt., "Garden,"	2622.50
Plumbago point, southerly end of Mission ridge,	1705.00
Lowest point between Kearsarge and Black mountain,	2426.67
Lowest point between Mission ridge and Black mountain,	2252.55

7. Railroad Surveys in Northern New Hampshire.

Heights along Boston, Concord & Montreal Railroad, and Mt. Washington Branch.

The records of this road having been lost by fire, the altitudes published in Guyot's Memoir on the "Appalachian Mountain System," which were derived from the original

records, are here given, with others from a published plan and profile of a survey for this road between Woodsville and Lancaster, by J. L. Gregg, engineer, in 1849. These altitudes are known to be approximately in agreement with other series foregoing, by comparison at Lake Winnipiseogee, at Wells River, and at the junction of the Mt. Washington Branch with the P. & O. Railroad. Several heights in the vicinity of Bethlehem, and others from the recent surveys north from Littleton and for the Mt. W. Branch, have been furnished by engineers H. W. Goodrich and R. S. Howe.

	Distances from Concord.	Heights in feet.
Meredith Village,	37 miles.	542
Plymouth,	51 "	473
Rumney,	59 "	520
Warren,	71 "	736
Railroad summit, Warren,	75 "	1063
East Haverhill,	79 "	773
Woodsville,	93 "	448
Connecticut river, low water,		407
Bath,	97 "	521
Near dam in Landaff,	101 "	560
Lisbon,	103 "	577
Upper village in Lisbon,	104 "	592
North Lisbon,	108 "	667
Littleton,	113 "	817
Scythe factory,	114 "	862
Stevens mills, Bethlehem,	118 "	987
Wing Road junction,	120 "	1019
Whitefield,	123 "	931
Dalton,	128 "	866
South Lancaster,	131 "	867
Lancaster,	134 "	870
Groveton Junction,	143 "	901
Bethlehem,	122 "	1187
Twin Mountain station,	129 "	1375
Junction of Mt. Washington Branch with P. & O. R.,	131 "	1483
Island below Richardson's mill, Bethlehem hollow,	122 "	1104
Pierce's mill-pond,	124 "	1218
Lower Ammonoosuc, at mouth of Little river,		1329
Lower Ammonoosuc, ½ mile above Carroll bridge,		1348
Burbank's mill-pond, near Twin Mountain house,	129 "	1365
Rounsevel & Colburn's mill-pond,	131 "	1430
White Mountain house,	133 "	1556
Fabyan house,	134 "	1571

	Distances from Concord.	Heights in feet.
Ammonoosuc station, base of Mt. Washington,	140 miles.	2668
Summit of Mt. Washington,	143 "	6293

Heights along the Grand Trunk Railway.

Copied from tracing of profile furnished by C. J. Brydges, Manager, and reduced to mean tide by connection with the special survey along Connecticut river, as previously noticed (p. 251). This profile thus referred to sea level indicates for Gorham a height 10 feet greater than that given for this railroad station by Guyot, from which base his determinations of altitudes among the White Mountains were probably computed. (See note beyond.)

	Distances from Portland.	Heights in feet.
Line between Maine and New Hampshire,	82 miles.	713
Shelburne,	85 "	723
Gorham,	91 "	812
Berlin Falls,	97 "	1035
Milan summit,	102 "	1087
Milan water-station,	103 "	1080
West Milan,	109 "	1015
Stark water-station,	114 "	990
Stark,	116 "	972
Bridge over Upper Ammonoosuc river,	117 "	961
Groveton,	122 "	901
Stratford Hollow,	126 "	877
North Stratford,	134 "	915
Nulhegan, Vt.,	139 "	1125
Wenlock, Vt.,	141 "	1162
Island Pond, Vt.,	149 "	1197
Summit, highest between Portland and Montreal,	156 "	1385
Norton, Vt.,	160 "	1357
Boundary Line station, P. Q., 132 miles from Montreal,	165 "	1232

8. Heights of Villages.

Abbreviations. L., Spirit Level; P. L., Pocket Level; T., Trigonometrical; B., Mercurial Barometer; A., Aneroid Barometer. After names of mountains, G. signifies measurements made by Prof. Arnold Guyot, LL. D., of Princeton, N. J.; J. those taken by Dr. Charles T. Jackson, as published in his final report on the geology of New Hampshire. Many of them have been calculated for the present chapter from the observations printed in that volume. The trigonometrical measurements were made by the United States Coast Survey, mostly under the direction of Prof. E. T. Quimby.

ROCKINGHAM COUNTY.

	Heights in feet.		Heights in feet.
B. Portsmouth, J.,	43	B. Deerfield, J.,	494
B. Newington, J.,	150	L. Raymond,	198
B. Kingston, J.,	75	L. Exeter,	62
B. Hampstead, J.,	313	A. Seabrook,	62
B. Durham, J.,	125	A. Newton,	156
A. South Newmarket,	134	A. Plaistow,	96
A. West Epping,	163	A. Derry, east,	358
A. Northwood,	590	A. Greenland,	51
B. Nottingham Square, J.,	450		

HILLSBOROUGH COUNTY.

L. Pelham,	134	A. East Weare,	388
A. Hollis,	300	L. North Weare,	489
A. Brookline,	400	A. Weare,	620
L. Greenville,	803	A. Deering,	972
L. New Ipswich, hay-scales, lower part,	944	L. Hancock,	826
A. Thornton's Ferry village,	148	B. Amherst, court-house, J.,	427
L. East Wilton,	330	B. Francestown, J.,	733
T. Antrim, middle of belfry window in South church,	766	B. Mont Vernon, J.,	770
T. Antrim, ridge-pole of brick ch.,	718	B. Lyndeborough, J.,	774
L. Greenfield, near hotel,	835	B. Temple, J.,	720
L. Peterborough,	744	L. Hudson,	203
		L. Goffstown (Parker's),	319
		L. Hillsborough,	674

Nashua. Levelling for water-works.

Datum for city levels (low water in Merrimack river),	93.10
Main street, at city hall and at Worcester depot,	152
Dam at Mine falls,	152
Dam below Main Street bridge,	116
Reservoir of water-works,	247
Pumping-station of water-works,	115
Pratt's hill, 1½ miles south of city,	252

Manchester. Levelling for water-works.

Cistern of barometer, corrected from statement on page 144,	235
City hall door-step,	217
Amoskeag base line (datum for city levels),	108.98
Amoskeag Co.'s reservoir,	324
Lake Massabesic,	256

	Heights in feet.
Stevens pond,	322
Dorr's pond,	290
Mudsill at Maple Falls dam, Candia,	407
Sawyer pond, Hooksett,	429
Moody pond, Hooksett,	439

CHESHIRE COUNTY.

B. Chesterfield, J.,	869	A. Stoddard,	1412
A. Fitzwilliam,	1150	A. Gilsum,	926
A. Richmond,	1180	A. Walpole,	365
B. Hinsdale, J., (?)	397	L. Harrisville,	1334
A. Jaffrey,	1057	L. East Rindge,	1003
L. East Jaffrey,	1032	B. Alstead, J.,	535
L. Troy (railroad),	1002	L. Paper Mill Village,	475

STRAFFORD COUNTY.

L. Rochester,	226	B. Strafford (Wingate's), J.,	748
L. Barnstead Parade,	512	A. Milton Three Ponds,	409
L. Barnstead Centre,	527	L. Barrington, railroad station,	207
L. Salmon Falls,	107	A. Middleton,	709
L. Great Falls, railroad,	178	A. New Durham Corner,	541
L. Dover, railroad,	72	L. Madbury (railroad),	108
Farmington (est.),	300		

BELKNAP COUNTY.

L. Gilmanton Iron Works,	647	A. Belmont,	538
B. Gilmanton Corner, J.,	918	A. Tilton,	478
T. Sanbornton Square town-house (ridge-pole),	930	T. Tallest church spire, Laconia,	568
		L. Meredith Village,	542
A. Farrarsville,	635	A. Center Harbor,	553

MERRIMACK COUNTY.

L. Pittsfield depot,	493	A. Wilmot,	846
B. Epsom, J.,	444	T. Webster (Corser hill church),	786
B. Dunbarton, J.,	799	L. Pittsfield, Baptist church,	520
L. Hooksett, railroad,	206	L. Henniker,	455
B. Franklin, upper village,	343	L. Contoocook,	373
L. Andover, railroad,	628	L. West Concord,	354
L. Potter Place, railroad,	653	L. Dimond's Corner,	425
Boscawen (est.),	300	L. High school-house sill, Warner,	498
T. Shaker barn ridge-pole, Canterbury,	815	L. Bradford,	679
		L. Webster,	555

	Heights in feet.		Heights in feet.
L. North Salisbury, . . .	602	T. Pembroke, Cong. church, base of spire, ...	446
B. Salisbury Centre, on hill, J., .	1007		

Concord. Levelling for water-works.

Datum for city levels (low water in Merrimack river), ...	225.29
Summit of hill on School street, ...	367
Former height of Long pond (Penacook lake), ...	404.5
Top of city water-works dam, ...	412
Little pond, ...	651
Sand bluffs, east of river, ...	350
State house, ...	292

SULLIVAN COUNTY.

	Heights in feet.		Heights in feet.
A. Washington, ...	1298	L. Claremont, ...	567
B. Acworth, J., ...	1397	L. Newport court-house, . .	822
L. Charlestown, ...	375	A. East Croydon, ...	884
B. Meriden, J., ...	912	A. Grantham, ...	924
A. East Lempster, ...	1090	A. Springfield, ...	1239
L. Cornish Flat, ...	855		

GRAFTON COUNTY.

L. Lebanon, town hall, . .	524	L. Danbury, ...	826
West Lebanon, ...	386	L. Grafton Centre, . . .	872
L. East Lebanon, ...	766	L. Hanover, ...	545
L. Enfield, ...	768	L. Mill Village, Hanover, . .	757
L. East Canaan, ...	956	B. Lyme, J., ...	484
L. Plymouth, railroad, . .	473	A. Hebron, ...	633
L. Rumney, railroad, . . .	520	Orford, ...	438
L. Warren, ...	736	B. Piermont, J., ...	460
L. East Haverhill, ...	773	A. Wentworth, ...	616
A. Bath, ...	530	A. South Groton, ...	640
Lisbon, ...	567	B. Haverhill, J., ...	710
B. Bethlehem, G., ...	1450	L. Littleton, railroad, . . .	817
B. Franconia, G., ...	921	L. Woodsville, ...	448
B. Profile house, G., . . .	1974	A. Campton, ...	594
B. Thornton, G., ...	1223	A. Ashland, ...	475

CARROLL COUNTY.

A. Drakesville, Effingham, . .	381	L. North Conway, ...	521
L. Wakefield, ...	700	L. Jackson, ...	759
L. Conway Corner, ...	466	L. Upper Bartlett, ...	660

	Heights in feet.		Heights in feet.
L. "Jericho village," near Mead's house, on Rocky Branch, 1 mile above junction with the Saco, ...	784	A. Freedom, ...	396
L. Nute's house, on ridge between Jericho and Goodrich falls, .	905	A. South Tamworth, . . .	630
L. Jackson road, at Goodrich falls,	708	A. Sandwich, ...	648
		A. Ossipee, Water Village, . .	745
		A. Tuftonborough, . . .	889
		A. Moultonborough Centre, .	581

COÖS COUNTY.

L. Whitefield, ...	957	L. Shelburne, ...	723
L. Sumner house, Dalton, . .	898	L. Berlin Falls, ...	1035
L. Groveton, ...	901	L. West Milan, ...	1015
L. Lancaster, ...	870	L. Stark, ...	972
A. Stratford Hollow, . . .	897	L. Colebrook, ...	1030
L. North Stratford, ...	915	L. Crawford house, . . .	1899
West Stewartstown, . .	1055	L. Fabyan house, . . .	1571
A. Jefferson mills, ...	1180	L. White Mountain house, . .	1556
L. Gorham, ...	812		

9. Heights of Mountains.

ROCKINGHAM COUNTY.

	Heights in feet,		Heights in feet.
B. Mt. Pawtuccaway, Not'gh'm, J.,		B. Harvey hill, J., ...	519
" " lower summit, .	780	B. Saddleback mt., Northwood, J.,	1032
" " middle summit,	892	B. Boar's Head, Rye, J., . . .	60–70
" " upper summit, .	827		

HILLSBOROUGH AND CHESHIRE COUNTIES.

T. Barrett hill, Greenville, . .	1271	A. Kidder mountain, New Ipswich,	1492
T. Bald mountain, Antrim, . .	2039	B. Temple mt., Temple, J., . .	1755
T. Pack Monadnock, Peterboro',	2289	T. Monadnock, Jaffrey, .	3186
T. Barrett mountain, New Ipswich,	1847	T. Mt. Pitcher, Stoddard, .	2170
T. Uncanoonuc, east peak, Goffst'n,	1333	A. Bald hill, Gilsum, . . .	1164
T. Crotched mt., Francestown,	2066	T. Duncan hill, Hancock, .	2003
B. Symmes hill, Hancock, J., .	1317		

STRAFFORD AND BELKNAP COUNTIES.

T. Gunstock, C. S. station, . .	2394	A. Wadleigh's hill, Meredith, .	860
B. Mt. Belknap, J., ...	2062	A. Sunset hill, Center Harbor, .	885
T. Gilmanton peak, . . .	1479	B. Blue mountain, Milton, J., .	1415
B. Blue mountain, Strafford, J., .	1151		

MERRIMACK AND SULLIVAN COUNTIES.

T. Bald Mink hill, Warner, .	. 1528	T. North Putney hill, Hopkinton,	856
T. Craney hill, Henniker, .	. 1420	T. Fort mountain, Epsom, .	. 1428
T. Catamount mt., Pittsfield,	. 1341	B. McKoy's mountain, Epsom, J.,	1590
T. Rattlesnake hill, Concord,	. 783	T. Ragged mountain, Andover,	2256
T. Stewart's peak, Warner,	. 1808	L. Mt. Kearsarge, Warner, .	. 2943
T. Croydon mountain, Croydon,	. 2789	T. Bean hill, Northfield, .	. 1515
T. Melvin hill, Springfield, .	. 2134	T. Lovell's mountain, Washington,	2487
T. Sunapee mountain, Newbury,	2683		

CARROLL COUNTY.

P. L. Mt. Crawford, G., . .	3134	T. Red hill, north peak, .	. 2038
Mt. Resolution, . . .	3400	B. Ossipee mountain, J., . .	2361
Giant's Stairs, ...	3500	A. Green hills, Conway, . .	2390
P. L. Trimountain, G., . .	3393	Tin mountain, Jackson, . .	1650
Silver Spring mount. (est.),	3000	Mt. Baldface, Jackson, . .	3600
P. L. Green's Cliff, G., . .	2958	B. Double Head, Jackson, J., .	3120
P. L. Table mountain, 3 miles S. S.E. from Hart's Ledge, G.,	3305	Duck Pond mountain, near Hart's Location (est.), .	2000
Mt. Israel, Sandwich, .	2880	Iron mountain, Bartlett (est.),	2000
B. Gt. Moose mt., Brookfield, J.,	1404	Mote mountain, Albany, .	3200
Cropple Crown, Br'kfield, Fogg,	2100	Mote mountain, south peak, .	2700
P. L. Mt. Chocorua, G., . .	3540		
T. Mt. Pequawket,* C. S., .	. 3251	T. Mt. Pleasant (Me.), C. S.,	. 2021
B. Red hill, south peak, G., .	1769		

GRAFTON COUNTY.

T. Moose mountain, Hanover,	. 2326	P. L. Tripyramid, G., . . .	4086
T. Mt. Cuba, Orford, . .	. 2927	Mt. Passaconnaway, . .	4200
T. Prospect mount., Holderness,	2072	P. L. Mt. Osceola, G., "Mad River peak,"	4397
T. Mt. Cardigan, Orange, .	. 3156	A. Mt. Osceola, ...	4400
T. Bristol Peak, Bristol, .	. 1785	B. Mt. Osceola, Bond, . .	4400
T. Ford hill, Grafton, . .	. 1800	B. Black mountain, "Sandwich Dome," G., ...	3969
T. Stinson mountain, Rumney,	. 2707	A. Black mountain, "Sandwich Dome,"	4050
Mountains in Waterville.		T. Black mountain, "Sandwich Dome,"	. 3999
A. Welch mountain, . . .	3500	*Mountains in Pemigewasset.*	
T. Mt. Whiteface, . . .	. 4007	P. L. Mt. Hancock, "Pemigewasset peak" of Guyot, . .	4420
B. Tripyramid, Bond's four peaks, from south to north, 4100, 4100, 4200, 4000			
A. South Tripyramid, . . .	4040		

* Erroneously stated to be 3300 feet on page 201.

	Heights in feet.
B. Mt. Carrigain, G.,	4678
B. Mt. Carrigain, east spur, G.,	4419
Mt. Nancy, Bond,	3800
P. L. Mt. Lowell, G., "Brick-house mountain,"	3850
Peak between Mts. Nancy and Lowell, Bond,	4000
P. L. Mt. Willey, G.,	4300
P. L. Highest p'k of Willey chain,	4330
P. L. Mt. Field (G.?),	4070
P. L. "Echo mountain," Guyot,	3170
P. L. Twin mountain, G.,	4920
" " Bond,	5000
Two peaks south of Twin, Bond,	4900, 4800
Mt. Flume, Bond,	4500
Mt. Liberty, Bond,	4500
So. end of Lafayette range,	4500
B. Mt. Lincoln, G.,	5101
T. Mt. Lafayette, Franconia,	**5259**
P. L. Mt. Kinsman, G., about	4200
P. L. Blue mountain, highest of the Kinsman range, G.,	4370
B. Mt.Cannon(Profile),G.,approx.,	3850

	Heights in feet.
B. Bear mountain,	3400

Mountains in Warren.

P. L. Mt. Black,	3571
P. L. Mt. Kineo,	3427
P. L. Mt. Cushman,	3326
P. L. Mt. Waternomee,	3022
P. L. Mt. Mist,	2243
P. L. Webster Slide mountain, G.,	2210
Mt. Sentinel,	2032
P. L. Mt. Carr, G.,	3522

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P. L. Owl's Head, Benton, G.,	2992
T. Moosilauke mount., Benton,	**4811**
B. Sugar Loaf, Benton, J.,	2565
A. Peaked hill, Bethlehem,	2042
B. Gilmanton hill, summit between Franconia and Littleton, G.,	1329
B. Campton mountain, Campton,	2879
B. Baldtop mount., Wentworth, J.,	2050
B. Squam mountain, Holderness,	2162
B. Piermont mountain, Piermont,	2167

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T. Mt. Ascutney, Windsor, Vt.,	3186

COÖS COUNTY.

B. Mt. Dustan, College grant,	2575
B. Half-moon mt., " "	2526
B. Mt. Ingalls, Shelburne,	2520
B. Hampshire hills, Cambridge,	1882
B. South spur of do.,	2141
B. Randolph mt., Randolph,	3043
A. South peak, Kilkenny,	3827
A. Long mountain, Odell and Stark,	3777
A. Green's ledge, Kilkenny,	2708
A. Jewell hill, Whitefield,	1467
A. Mt. Pisgah, Clarksville,	0000
Pilot mountain,	3640
Mt. Starr King,	3800
A. Peak in Erving's Location,	2786
A. Mt. Lyon, Northumberland,	2735
B. Percy north peak, Stratford,	3336
B. Percy south peak, Stratford,	3149
A. Mt. Forest, Berlin,	1950
A. Chickwalnipy, Success,	1460
Sugar loaf, Stratford, estimated,	3470
B. South hill, Stewartstown, J., about	2000
B. Mt. Carmel, J.,	3711
L. Mt. Washington (see p. 59),	**6293**
B. Mt. Adams, G.,	5794
B. Mt. Jefferson, G.,	5714
B. Mt. Clay, G.,	5553
B. Mt. Monroe, G.,	5384
B. Little Monroe, G.,	5204
B. Mt. Madison, G.,	5365
B. Mt. Franklin, G.,	4904

	Heights in feet.		Heights in feet.
B. Mt. Pleasant, G.,	4764	P. L. Wildcat mountain, G.,	4350
B. Mt. Clinton,	4320	P. L. Mt. Carter, south peak, G.,	4830
Mt. Jackson, Bond,	4100	P. L. Mt. Carter, north peak, G.,	4702
Mt. Webster, Bond,	4000	P. L. Mt. Moriah, G.,	4653
P. L. Cherry mt., approximately, G.,	3670	Mt. Royce, Bean's purchase,	2600
B. Mt. Deception, G.,	2449		

Miscellaneous.

B. Molybdenum mine, Westmoreland, J.,	999	P. L. Eagle cliff, facing Profile house, G.,	3446
B. McCrillis's house, Sandwich,	1083	B. Eagle head, near the pond,	4216
B. Copper mine, Warren, J.,	1450	B. Eagle pond, foot of last peak,	4170
B. Ashuelot river, Winchester, J.,	377	B. Pierce's bridge (Bethlehem station), G.,	1221
B. Neal's house, Unity, J.,	787	B. Peabody river, path over near Glen house, G.,	1543
B. S. Johnson's, Cornish, J.,	1093	L. Glen house,	1632
B. Madison lead mine, J.,	509	B. Cascade, ¼ mile east of notch between Sawyer's river and Hancock Branch waters,	2076
B. Limestone quarry, Orford,	1751	A. Greeley's hotel, Waterville,	1553
B. Spofford's pond, Chesterfield, J.,	738	A. Table rock, Dixville notch,	2454
B. Pleasant pond,	594	B. Francestown, soapstone quarry, J.,	666
B. Round pond,	324		
B. Echo lake, Franconia, G.,	1926		
B. Cabin, foot of Mt. Lafayette, G.,	1780		
B. Flume house, road in front, G.,	1431		

NOTCHES ABOUT THE WHITE MOUNTAINS.

L. White Mountain notch,	1914	L. Between Littleton and Whitefield,	1057
B. Cherry mt., road summit, G.,	2192	L. Milan summit,	1087
B. Between Moose and Israel rivers, G.,	1446	A. Between Nash and Sims str'ms,	1715
B. Pinkham Notch summit, south of Glen house,	2018	B. Dixville notch,	1831
A. Pinkham Notch summit, north of Glen house,	1790	A. Robert's notch, Odell,	2263
A. Between Woodstock and Landaff,	1655	A. Between Sandwich and Campton,	1417
A. Between Franconia and Bethlehem,	1820	B. Franconia notch, G.,	2014
Between Bethlehem station and Gale river (est.),	1420	B. Between New Zealand river and east branch of Pemigewasset,	2123
Between Twin Mountain house and Whitefield (est.),	1525	B. Willey notch, between Ethan's pond and Saco river,	2799
		B. Between Mts. Nancy and Lowell, near a pond,	3224
		B. Carrigain notch (north),	2465

	Heights in feet.		Heights in feet.
B. Between Sawyer's river and tributary of Hancock branch,	3126	B. Mad River notch, near Greeley ponds, ...	1815
B. Between Swift river and east branch of the Pemigewasset,	2618		

NOTE. The gaps between the principal White Mountains have been given at the close of the preceding chapter.

For further heights on the Merrimack, Connecticut, and other rivers, see altitudes along the boundaries of New Hampshire in the chapter on topography, and tables given in description of river systems in a following chapter.

10. Heights along Geological Sections.

SECTION I. *From Lawrence, Mass., to South Vernon, Vt., along the Massachusetts line.*

Lawrence, Mass., top of Essex Co.'s dam, ...	39	Top of gravel moraine terraces, .	1364
Lawrence, Essex street, . .	65	Brook, ...	1255
State line, ...	138	G. Stratton's, New Ipswich, .	1301
Beaver creek, Pelham, . . .	126	Hill east of S. F. Hale's, Rindge,	1364
Pelham village, ...	134	Railroad in Rindge, . . .	1064
J. Gage's house, ...	156	1 mile west of Rindge village, .	1254
East line of Hudson, . . .	215	Peasley pond, ...	1026
D. Davis's house, Hudson, . .	218	Fitzwilliam hotel, . . .	1150
Railroad bridge over Merrimack river,	126	Fitzwilliam depot, . . .	1063
Merrimack river, ...	93	Hill, cross-roads, . . .	1168
Railroad junction, ...	134	Brook Tully, ...	1077
Nashua, city hall, ...	152	Ridge at sharp fork in road, .	1150
West line of Nashua, . . .	180	Rice brook, ...	1030
Hollis village, ...	300	Richmond village, . . .	1180
Brook, ...	250	Summit west of pail factory, .	700
Proctor hill, ...	425	Town line, Richmond and Winchester,	415
Plain, ...	370	East side of Muddy brook, . .	350
Brookline village, ...	400	Muddy brook, ...	320
P. Sanders's house, . . .	550	Plain, O. Barrett estate, . .	350
Mrs. Putnam's house, . . .	760	East of L. Warner's house, . .	400
Railroad, east part of Mason, .	700	E. Hammond's house, . . .	650
Brook, ...	733	Asahel Lyman's house, . .	495
Ridge, ...	930	Perchog river, ...	295
Ellis house, ...	1070	West of Elijah Smith's house, .	285
Greenville, railroad, . . .	803	S. H. No. 16, Hinsdale, . .	288
Greenville, Souhegan river (beyond railroad), ...	792	Sand moraine terraces, . .	305
Hay scales, New Ipswich, . .	944	Fourth terrace, Connecticut river,	262
Summit of Kidder mountain, .	1492	Railroad bridge over Conn. river,	236
Brook, ...	1245	Second terrace, ...	224
		Connecticut river, water, . .	200
		South Vernon station, Vt., . .	261

SECTION II. *From ocean at Seabrook, to Brattleborough, Vt.*

	Heights in feet.		Heights in feet.
Meadow in Seabrook,	10	Main street, East Wilton,	330
School-house,	22	Bridge west of village,	364
Washington house, Seabrook,	62	F. Billings's house,	606
Top of drift moraine,	94	Church in Wilton,	614
Hampton Falls river (tributary),	43	J. Kendall's,	1028
E. Flanders's house,	140	J. Killam, cross-road,	900
Powwow river,	34	S. W. Billings's,	1100
Newton village,	156	Peterborough,	744
Plaistow village,	96	M. Fairbanks's house,	1010
Railroad (B. & M.),	86	Jaffrey Centre,	1057
D. Noyes's house,	230	Summit of Monadnock,	3186
Hampstead church,	313	Lower limit of slates on Monadnock,	2135
Nashua & Rochester Railroad crossing,	258	Railroad, Troy,	1002
Derry east village,	362	Bridge beyond L. Dickinson's, Swanzey,	1072
Derry depot (M. & L. R.)	238	West Swanzey bridge,	1022
Pinkerton cemetery,	440	Outlet of Spofford lake,	738
Merrimack river, Litchfield,	104	Chesterfield village,	864
Thornton's ferry, village,	156	Connecticut river,	214
Bridge over Souhegan river,	242	Railroad, Brattleborough, Vt.,	228
Railroad, near Danforth's Corner,	256		

SECTION III. *From Portsmouth to Walpole.*

Portsmouth, Brewster's, C. T. J.,	43	Near town line, Raymond,	445
Portsmouth, Franklin house,	27	Near H. M. Eaton's, Candia,	529
Hill of gravel,	59	Railroad, Candia depot,	445
Greenland church,	51	Hill, west,	659
Greenland (railroad),	59	Old railroad summit, Kinnecum swamp,	528
N. Adams's, fork in road,	139	Rowe's Corner,	453
Swampscott river,	00	Sawyer's pond,	429
South Newmarket,	134	Campbell's hill,	300
Newmarket Junction,	52	Merrimack river,	180
Sienite at cross-roads,	88	H. & J. Austin's, Hooksett,	600
Brook in Newmarket,	76	L. & R. Woodbury's, Bow,	760
Epping depot,	154	Last house in Bow,	720
West Epping,	163	High land,	632
Ordway's,	234	School-house,	560
Raymond depot,	198	Kimball's pond,	488
Lamprey river, west of village,	174	A. Prescott's house,	672
Jones pond,	258		

	Heights in feet.		Heights in feet.
Dunbarton Centre,	799	Contoocook river,	535
H. Jameson's house,	600	D. Cooledge's house,	800
East Weare,	388	South end North Branch Village,	806
Railroad, East Weare,	395	Ridge, west part of Antrim,	1313
R. Peaslee's house,	452	Island pond, Stoddard,	1248
Mt. William, Weare,	960	Stoddard village,	1412
Brook, west,	540	E. Locke's house,	1562
Weare Centre,	620	F. Pitcher's house,	1402
L. & W. B. Gove,	848	Gilsum village,	926
Hill,	946	Bald hill,	1164
Clinton Grove,	896	School-house No. 1, Surry,	560
West of J. B. T. P.,	976	Ashuelot river,	530
M. A. Hodgdon's house,	664	D. Marsh's estate,	1300
J. Downing's,	808	Fisher brook,	721
Deering village,	972	Old church, Walpole,	753
Near S. Carr's house,	948	Walpole village,	365
I. McKean's house,	995	Cheshire Railroad,	277
N. C. Ferry's house,	775	Connecticut river,	225

SECTION IV. *From Great Falls to Charlestown.*

Salmon Falls river,	166	High terrace,	350
Railroad at Great Falls,	178	Meadow,	245
Hotel, Great Falls,	200	Merrimack river,	227
Academy,	237	Railroad, West Concord,	354
Summit at Horne's,	365	Hill, J. P. Nelson, Concord,	629
Rochester,	226	Contoocook,	373
Bridge, Isinglass river, near G. McDaniel's,	150	4 ms. W. of Cont'cook, in Henniker,	600
		Town line, Henniker and Warner,	795
S. H. north of Judge Hale farm, Barrington,	160	Day pond,	635
		Bradford pond,	670
House, G. & C. Caverly, Barrington,	575	Hill, Bradford, east Rev. H. Holmes's,	914
Bow lake,	525	E. Washington, guide-board,	851
Hill, J. W. Knowley,	700	Brook, R. Spaulding,	1060
Northwood centre,	590	Foot of Lovell's mt., J. Severance,	1325
Northwood summit,	640	Lovell's mountain, top,	2492
Summit, J. Emerson,	496	Washington village,	1298
Epsom,	444	1 mile west,	1523
Suncook river, mouth of Little Suncook,	338	Pollard's saw-mill, Ashuelot river,	1273
		Summit, Lempster mountain,	1440
Meadow, W. edge of Epsom,	364	Base, do., turn in road,	1240
Hill, J. Masowe, Chichester,	690	Dodge pond,	1075

	Heights in feet.		Heights in feet.
East Lempster,	1090	Summit near J. P. Davis's,	1410
Summit near H. Fuller's,	1250	Valley,	1150
Keyes's hollow,	990	Prospect hill,	1200
Hill (P. W. Pettengill),	1260	Terrace, Hackett's brook,	610
Moose brook,	1130	Hill,	610
Lynn,	1350	Village and depot, Charlestown,	375
Valley, west,	1280	Connecticut river,	290
Acworth village,	1397		

SECTION V. *Milton Mills to Windsor, Vt.*

Milton Three Ponds,	409	West town line,	473
Salmon river,	437	Winnipiseogee river, first crossing,	382
S. Remick's house,	441	" " second "	346
S. H., branch of Salmon river,	412	Pemigewasset river,	328
Union Village, railroad,	500	Webster house, Franklin,	345
L. H. Cook's, Middleton,	604	Railroad, Franklin,	363
Brook,	485	Chance pond,	446
Middleton,	709	East Andover,	661
B. F. Savage's,	605	Andover,	628
New Durham Corner,	541	Potter Place,	653
J. Randall's,	661	Wilmot Centre,	846
Merry-meeting lake,	589	S. B. Brown's,	1102
Beyond school-house (Varney's),	925	Summit, S. J. Silver's,	1383
Winnipiseogee lake,	500	O. C. Howard's,	1207
Hotel, Alton bay,	530	Station pond,	1303
Summit in road, west,	943	West Springfield,	1239
Place pond,	799	Grantham,	924
J. D. Nelson's,	807	East Croydon,	884
Valley,	635	Smith's,	1132
M. Price's,	738	Cross-roads,	1068
Summit, west of Hill's,	1103	Croydon mountain (road),	1700
Town line between Gilmanton and Belmont,	943	Cornish Flat,	855
		H. H. Day's,	1295
S. C. Edward's,	663	Hilliard's,	1135
Farrarville,	635	Methodist church,	580
Belmont,	538	Connecticut river,	304
Brook in Northfield,	490	Windsor, Vt. (depot),	331
Tilton (railroad),	478		

SECTION VI. *Effingham to Norwich, Vt.*

Maine line,	390	Pine River,	437
Drakesville,	381	Duncan lake,	569

	Heights in feet.		Heights in feet.
Summit, railroad, ...	654	Meadow, ...	602
Brook, ...	700	Hebron village, ...	633
Wm. Goldsmith's, . . .	1040	Groton post-office, . . .	640
Ossipee, Water village, . .	745	Mountain range, estimated, . .	2137
W. Palmer's, ...	1021	N. & N. Woods, Jr., Canaan, .	1121
Tuftonborough Corner, . .	889	H. K. Farnham's house, " .	1037
Moultonborough Corner, . .	689	Goose pond, " .	700
Moultonborough Centre, . .	581	Hill porphyritic gneiss, " .	1030
T. S. Adams's, ...	553	Committee Meadow brook, Hanover,	925
Long pond, ...	505	R. Goss's, "	1128
Winnipiseogee lake, . . .	500	Moose mountain range, "	1800
Senter house, ...	553	Valley, "	1300
Sunset hill, ...	885	Hill east of Mill village, .	1280
Summit, S. P. Merrill's, . .	713	Mill village, Hanover, . .	756.8
White Oak pond, ...	629	Corey hill (not highest point)	671.1
Ashland depot, ...	450	Agricultural College farm-house,	500
Ashland, ...	475	C. H. Hitchcock's house, floor,	519.4
Railroad crossing, ...	500	Cistern of barometer, Shattuck observatory, ...	603.7
Half mile east of Hebron line, .	1027	Hanover plain, ...	545
Line between Plymouth and Hebron, ...	1074	Conn. river at Ledyard free bridge,	375.2
Hill north of road, ...	1900	Railroad station, Norwich, . .	406
Summit of road, ...	1401	Norwich village, ...	550
Newfound lake, ...	597	Hill west, ...	830

SECTION VII. *From Freedom, through Orford, to Vershire (Vt.) copper mine.*

State line, ...	450	Hill in Ellsworth, ...	1080
Hill east of Freedom village, .	720	Stinson pond, ...	990
Freedom village, ...	396	Mt. Carr, ...	3522
Danforth bridge, water, . .	409	Wentworth, ...	636
Eastern Railroad, West Ossipee, .	428	Cuba Mountain ridge, ...	1620
South Tamworth, ...	630	Valley of Jacob's brook, . .	810
Sandwich village, ...	648	Bass hill, ...	1000
Top Israel's mountain, Sandwich,	2880	Ridge east of Connecticut river, .	864
Summit of road from Sandwich to Campton, ...	1417	Connecticut river, ...	410
Campton village, ...	594	Passumpsic Railroad, Orford station, ...	438
Pemigewasset river, ...	500	Vershire copper mine, ...	702

SECTION VIII. *From Mt. Pequawket to Piermont.*

	Heights in feet.		Heights in feet.
State line,	500	Pollard's house, Woodstock,	1490
J. Stile's house,	750	Pemigewasset river,	1350
Top Shingle Pond Knob,	1000	Moose bridge,	1364
Top Mt. Pequawket,	3251	Blue ridge,	2000
Valley,	2158	Valley, west,	1800
Mountain, west,	2358	Moosilauke,	4811
Pendexter's house,	678	Oliverian brook,	1240
Terrace on Saco river,	530	Owl's Head (not the top),	1450
Saco river,	500	River,	1000
Hill, west,	1200	Railroad, B. C. & M.,	1063
Upper Bartlett plain,	664	Mountain west,	1800
Saco river, at line of Bartlett and Hart's Location,	749	Base of mountain,	1300
Sawyer's river, at highway bridge,	867	Saw-mill near Cross mine,	1100
Mouth of Carrigain brook,	1200	Piermont village,	460
Summit between Sawyer's and Pemigewasset rivers,	2500	Connecticut river,	420
Mouth of Hancock branch,	2025	Piermont railroad station (C. & P. R. R.),	440

SECTION IX. *Bean's Purchase to East Montpelier, Vt.*

Mt. Royce,	2600	Twin Mountain House station,	1375
Wild river, first crossing,	1580	Bethlehem station,	1187
Wild river, second crossing,	1950	Bethlehem village,	1450
Mt. Carter,	4702	Peaked hill,	2042
Glen house,	1632	Saddle,	1820
Peabody river,	1543	West Peaked hill,	1905
Half-way house,	3840	Railroad, Littleton,	817
Summit Mt. Washington,	6293	Littleton village,	835
Upper water tank, Mt. W. R. R.,	5800	Parker river,	760
Second tank (Jacob's ladder),	5468	Hill west,	930
"Waumbek Junction,"	3910	Milliken's saw-mill,	667
Ammonoosuc station,	2668	Gardner's mountain, north end,	1280
Fabyan house,	1571	Connecticut river,	450
White Mountain house,	1556	Barnet, railroad station,	467
Pool below lower falls of Ammo'c,	1503		

SECTION X. *Success to Lancaster.*

State line,	1925	Second valley,	1360
First valley,	1500	Second hill, east part of Berlin,	1480
Hill,	1600	Androscoggin river,	1012

	Heights in feet.		Heights in feet.
Berlin Falls station, G. T. R.,	1035	Jefferson Mills village,	1180
Mt. Forest, Berlin,	1950	Mt. Prospect,	1260
Dead river,	1545	Valley,	1135
Mountain west, Berlin,	2030	Mt. Pleasant,	1225
East spur of Starr King mountain,	3555	Connecticut river,	800
Starr King mountain,	3800		

SECTION XI. *From north line of Success to Groveton.*

State line,	1680	Stark water-station,	990
Burnside pond,	1280	Stark,	972
Chickwalnipy mountain,	1460	Devil's slide,	1200
Androscoggin river, Milan Corner,	1100	Groveton,	901
Milan hills,	1460	Connecticut river,	860
G. T. R., West Milan,	1015		

SECTION XII. *Umbagog Lake to Island Pond, Vt.*

Umbagog lake,	1256	Between Connecticut river and Mill brook,	1390
Hill, west,	1485	Mill brook,	1080
Bragg's bay,	1195	Between Mill and East Branch,	1296
Hill, west,	1615	East Branch,	1020
Millsfield pond,	1270	Between East and Black branches,	1400
Height, west,	1788	Black Branch,	1025
Branch of Phillips brook,	1545	Between Black and Yellow br'ches,	1200
Hill, west,	1762	Yellow Branch,	1060
Phillips Brook pond,	1525	Between Yellow and North br'ches,	1170
First ridge,	1820	North Branch,	1065
Second ridge,	1889	Between North Branch and McConnell's,	1260
Third ridge,	1956	McConnell's house,	1062
Height of land, west,	2167	McConnell's pond,	1123
Lyman brook,	1072	Island Pond,	1197
Hill,	1086		
Road by Connecticut river,	1025		
Connecticut river,	947		

SECTION XIII. *From Academy Grant to Holland, Vt.*

Maine line,	1705	Cedar stream,	1977
Ridge, west,	2212	Ridge, west,	2160
Branch of Dead Diamond,	1767	Dead water,	1844
Ridge, west,	2100	A. J. Barrett's,	2069
Little Dead Diamond,	1902	Young's house,	1692
Height, west,	2338	Top of hill, near school-house,	1609

	Heights in feet.		Heights in feet.
Bridge over Hall's stream,	1098	Height, west,	1270
Canaan bridge,	1054	G. T. R., boundary station,	1232
Last house, Canaan, Vt.,	1320	Height, west,	1423
Little Leach pond,	1175	Farm south of Barnstead pinnacle,	1440
Height, west,	1210	Bog south of Barnstead mountain,	1418
Great Averill pond,	1180	Barnstead road, in Holland, Vt.,	1242

SECTION XIV. *From Maine line through Second Connecticut Lake to Hall's stream above Colebrook Academy Grant.*

Maine line, near Prospect hill,	2182	Height of land between Perry and Indian streams,	2200
Hill nearest to Second lake,	2030	Indian stream,	1780
Second lake,	1903	Height of land between Indian and Hall's streams,	2325
First hill west of Second lake,	1980	Hall's stream above Colebrook Academy grant,	1740
Bog Brook valley,	1850		
Height of land between Bog brook and Perry stream,	2060		
Perry stream,	1900		

Section from Tin Mountain, Jackson, to Hancock Mountain.

Tin mountain, Jackson,	1650	Duck Pond mountain,	2000
Jackson village,	759	Duck Pond brook,	1400
South part of Cobb's hill,	1000	Mountain,	1900
Valley of Rocky Branch,	761	Carrigain brook, base of Mt. Carrigain,	1500
South part of Bald mountain,	1200	East spur of Carrigain,	4419
Brook,	775	Head of Sawyer's river,	3126
Mountain south of Crawford mt.,	2000	Hancock mountain,	4420
Saco valley,	1000		

Section through Warren.

Baker's brook,	1480	S. Whitman's,	997
N. Merrill's,	1681	J. Whitcher's,	1127
Gleason's saw-mill,	1168	B. C. & M. Railroad,	914
Saw-mill near E. Noyes's,	916	Kelley's summit,	1542
E. Noyes's,	966	Between ponds, Piermont,	1282

CONTOUR LINES.

We are now prepared to make a practical application of the long list of heights given with so much particularity. By noting their relations to the rise and fall of land, one can designate certain points where the land must be of a given height. Furthermore, after fastening upon a

multitude of points which seem to be exactly 500 feet above mean tide, we may connect them together by lines, and thus indicate the level of 500 feet wherever it may extend throughout the state. If it were possible to lay down a red cord from town to town, wherever this contour line extended, the means would be afforded for determining the exact height of much territory. The next best thing is to draw the course of the line upon a map. By drawing a series of them and coloring the areas between, one can get at a glance the relative elevations of all parts of the state. If skilfully prepared, such a map is invaluable.

We have endeavored to prepare such a chart, and present it in the atlas. The final sketch is not drawn at the moment of penning this description, but a general idea of its appearance will lead those interested to examine it in detail for themselves. We desire, also, to incorporate other facts which may still be within our reach before the final completion of our work. Such a sketch may be elaborated indefinitely. Our aim is to make use of a well engraved map of the state on copper, on the scale of eight miles to the inch, and draw upon it the contour lines for every successive five hundred feet of altitude. Twelve of them, therefore, can be represented within the state limits.

The 500-*feet Line.* This commences at Lake Newichwannock, between Wakefield, and Newfield and Acton, Me., the sources of Salmon river, and the south end of the straight east boundary. The line runs southwesterly into Milton, curving around parallel to the Portsmouth, Great Falls & Conway Railroad to Union Village, on the east side of the Fellows Branch river valley. It then follows the west border of the same valley into Farmington, returning northerly along the Dover & Winnipiseogee Railroad into New Durham. The line apparently follows back the other side of the Cochecho valley into Rochester, and turns up the Isinglass river and its branches, to within half a mile of Bow lake in Strafford. The line next passes more westerly from Barrington into Nottingham, Deerfield, and Candia, almost connecting with its course up the Suncook valley through Deerfield. From the west part of Candia it passes along the ridge east of Manchester, within two miles of Massabesic lake. Thence it doubles back in sight of the city of Manchester, and passes up the valley of Suncook river to Pittsfield, extending nearly to Suncook pond, or the tributary from Northwood. Thus nearly all of

Rockingham county lies below the level of 500 feet. There must be several islands, or insulated areas of land, above 500 feet to the south of the line as described.

From Pittsfield the line extends to the lower part of Chichester, and curves back north-easterly along the Soucook valley to the north part of Loudon. It then passes directly to Winnipiseogee lake, after curving nearly to the town of Concord, through Canterbury, Northfield, Belmont, and Gilford. The shore of Lake Winnipiseogee affords the most accurate notion of the course of our line in Belknap and Carroll counties, since the average height of the lake is just 500 feet. Returning down the valley, there is a great curve northwardly into Meredith, for the Winnisquam lake, thence the course is through Tilton and Sanbornton, crowding the Merrimack river opposite Bristol, and bordering the river into Campton and Rumney, the area between the lines varying somewhat in width.

On the west side of the Merrimack the return line cannot pass the barrier till we reach the edge of Concord. It then passes up the Blackwater valley into Salisbury. The line passes up to Warner on Warner river, and to Hillsborough on the Contoocook river. Rattlesnake hill, in Concord, becomes an island. From opposite the Mast Yard, in Concord, the line crosses to the Bow hills, turning in Hooksett and Goffstown to pass up to North Weare along the Piscataquog, with a branch to New Boston. The line returns through Bedford, and extends up the Quohquinapassakessananagnog creek into Amherst. On the Souhegan river the line may extend into the edge of Lyndeborough. The banks on this river through Wilton are high, and not far apart, so that the area below the level of 500 feet is long and narrow. The line seems to leave the state in the south-west corner of Brookline.

The line next enters the state in Winchester along the Connecticut valley, and extends to the Fifteen-miles falls in Monroe, curving north-easterly along the valleys of the tributaries. On the Ashuelot, the line extends a little ways above Keene. As the water-shed between the Ashuelot and Connecticut rivers continues to the village of Hinsdale as a prominent ridge, the area below five hundred feet is very marked on the map in the former valley. On Cold river, the line runs up to the edge of Acworth; on Sugar river, nearly to Claremont village; on Mascomy river,

to Lebanon village; and only a short distance up the other tributaries. It passes up the Passumpsic river five or six miles.

The 500-feet line passes a few miles into New Hampshire along the Ossipee and Saco valleys. The two contours almost connect on the Madison summit of the Portsmouth, Great Falls & Conway Railroad, and, on the Saco, the line passes to Lower Bartlett.

The 1000-*feet line.* On the Androscoggin this line extends to the top of Berlin falls, and to the west line of Gorham on Moose river. On the Saco it reaches to the mouth of Nancy's brook, near the residence of Dr. S. A. Bemis, also two or three miles up Sawyer's river, and above Jackson on the Ellis river. On Swift river it extends to the west part of Albany. It then follows the foot hills of the White Mountains to the junction of the main branches of the Pemigewasset river at North Woodstock, having run two or three miles into Waterville along Mad river. The line from the Pemigewasset passes into the valley of Baker's river to the north part of Warren, returning on the west side to Bridgewater, thence curves around Newfound lake, and can be traced to the valley of Smith river, whence it passes to the highest summit on the Northern Railroad in Orange. The railroad has been excavated beneath the thousand-feet level at this divide; but there are a few rods' width of the natural surface of the ground which rise above that level. The line next passes in a southerly direction to Massachusetts, curving very much easterly to pass around Mt. Kearsarge, returning to the railroad summit in Newbury, and reaching the towns of Jaffrey and Sharon on the Contoocook river before coming back to Deering and Weare on the east side of the same valley. The line leaves the state in New Ipswich.

The most prominent islands to the south-east of the line just described are the Eaton-Madison heights, Ossipee Mountain group, Green mountains in Effingham, the mountains between Strafford and Carroll counties, the Gunstock and Belknap range, Red hill, New Hampton and Sanbornton heights, Ragged mountains in Hill and Andover, and the Uncanoonucs in Goffstown.

On the west side of the Merrimack-Connecticut water-shed we find the area between the mill-pond and Troy, on the Cheshire Railroad, to be above one thousand feet, the line curving westerly from the south part of Fitzwilliam around Richmond to Troy. Thence it proceeds nearly to

Harrisville, thence into Marlow, around most of Alstead, and up the valley of Cold river into Lempster. The line returns so as to pass south of Acworth village, thence northerly, and north-easterly irregularly, nearly to Sunapee lake. The line now runs back among the hills on the north branches of Sugar river, even into Springfield, but meanders back to Claremont, and then passes northerly on the flanks of Croydon and Grantham mountains to East Lebanon, thence southerly to the Orange railroad summit, thence to the north line of Canaan, and westerly nearly to the gap between Moose and Smart's mountains, thence southerly to the south end of Moose mountain, and thence northerly to the Swift Water valley in Haverhill. Thence the line passes south-easterly towards the Woodstock notch, and thence irregularly to Franconia iron works, to North Lisbon, and up the Ammonoosuc river nearly to the Wing Road station. The Whitefield summit (Boston, Concord & Montreal Railroad) lies above one thousand feet; and, therefore, this contour returns to Littleton, passes around Palmer hill, and thence into Whitefield through Dalton. From the very bank of the Connecticut in South Lancaster the line runs into Lancaster, Northumberland, around Mt. Lyon, and up the Grand Trunk Railway into Stark and Milan. Returning, the line extends up the Connecticut to Columbia, and up Nulhegan river in Vermont two or three miles. Gardner's Mountain range in Lyman is the principal island west of this 1000-feet level on the Connecticut slope.

The 1500-feet line. In the south part of the state this line appears chiefly along the Merrimack-Connecticut water-shed, as a series of islands. First there are the Barrett, Pack Monadnock, and Monadnock series. Next, the heights in Nelson, Stoddard, Springfield, and the Sunapee range. On the east Mt. Kearsarge, and on the west Croydon, Grantham, Moose, Smart, Cuba, and Piermont mountains, reach above this line. Other areas are connected with the Cardigan range, Groton and Plymouth heights, Gunstock, Ossipee, and Green mountains. Another prominent expanse above 1500 feet lies east of Baker's river, in Wentworth, Warren, and Rumney.

The entire White Mountain area is encircled by this contour line, with very narrow strips of a lower level, marking off Pequawket and the Starr King group. There are two areas to the north above this line, one east of the Androscoggin valley, and the other north of the Grand Trunk

Railway. This line is reached on the Connecticut, near the "hollow," six miles below the lake.

Contours from 2,000 *to* 6,000 *feet high.* These are confined to comparatively small areas, and need not be described fully in the text. Only two mountains, Monadnock and Cardigan, south of the Boston, Concord & Montreal Railroad, exceed 3,000 feet, while Kearsarge and Cuba are nearly as high. In the same district the following exceed 2,000 feet: Bald, Pack Monadnock, Crotched, Pitcher, Croydon, Melvin, Sunapee, Ragged, Lovell's, Moose, Smart's, Piermont, Webster slide, and Mist. Near Winnipiseogee lake, Gunstock, Belknap, Ossipee, Green, Cropple Crown, Red Hill, Prospect, Israel, and Squam exceed the same figure. Nearly all the White Mountain elevations are more than 2,000 feet high.

North of the Grand Trunk Railway the following peaks exceed 2,000 feet: Ingalls, Half-moon, Dustan, Hampshire hills, Pisgah, Lyon, Percy peaks, Stratford mountains, Dixville range, peaks in Millsfield, Stewartstown, Atkinson and Gilmanton Academy grant, Webster, Mt. Carmel, and the highland boundary.

The special arrangement of the elevated contours about the White Mountains can be best understood by reference to the maps in the atlas. Washington is the only peak exceeding 6,000 feet. Eight are more than 5,000 feet high, viz., Adams, Jefferson, Clay, two Monroes, Madison, Lafayette, and Lincoln. Fourteen equal or exceed 4,500 feet, viz., Franklin, Pleasant, two Carters, Moriah, Carrigain, Moosilauke, Flume, Liberty, south peak of Lafayette range, four of Twin Mountain range, and perhaps others. Twenty equal or exceed 4,000 feet, viz., two Whitefaces, Passaconnaway, four of the Tripyramid, Osceola,—Sandwich Dome lacks only one foot of it,—Hancock, Willey, Field, one between Nancy and Lowell, highest peak of Willey chain, Kinsman, Blue, Wild-cat, Webster, Jackson, Clinton, and perhaps others. Twenty-eight equal or exceed 3,000 feet, viz., Crawford, Resolution, Giant's stairs, Tri-mountain, Silver spring, Table, Chocorua, Pequawket, Baldface, Doublehead, Mote, Welch, Echo, Profile, Black (Warren), Kineo, Cushman, Waternomee, Carr, Bear, Lowell, Nancy, Randolph, South, Long, Starr King, Pilot, Cherry, and others unnamed. Those above 2,000 feet are still more numerous.

Conclusions. From the presentation of the above facts, we may perceive that the land rises in passing north-westerly from the coast till the

main ridge or backbone of the state, described on page 210, is reached, averaging about twenty miles distant from Connecticut river. On the west of this ridge there is a gradual rise along the western boundary from two hundred to three thousand feet, or so that the head of the valley reaches the level of the summit ridge on the north border. The culminating point in the ridge is about one third of the way from the north boundary.

The following may show the general arrangement of the several areas: The south-east corner,—making, with the narrow Connecticut strip, about one sixth of the whole area of the state,—lies altogether below 500 feet. The 1000 to 1500-feet area, occupying about a fifth part of our territory, is situated mainly along the Connecticut-Merrimack ridge, skirting the White Mountains on the east, and then passing up the Androscoggin valley to Umbagog lake. The 500 to 1000-feet line embraces certainly two fifths of our area, and lies chiefly between the south-east 500-feet line and the Connecticut-Merrimack ridge,—the balance occupying the western slope of the state. About one sixth of our area reaches above 2000 feet; and the balance would be occupied by the 1500-2000-feet surface. This would place the average elevation of the state above the sea at about fourteen hundred feet.

With the exception of about one twelfth part of our territory, everything is susceptible of cultivation. There is good grass land in Stoddard 2170 feet above the sea, and perhaps higher, north of Colebrook. Forest trees grow to advantage to the height of 3000 feet among the White Mountains, and will flourish a thousand feet higher if protected from the stronger winds. At 4000 feet the animals and plants common in Greenland and Labrador begin to show themselves, and they extend universally above that level. In subsequent chapters the geographical distribution of animals and plants will be taken up in considerable detail.

NOTE. For the sake of perfecting the tables of heights, I have sent proof-sheets of this chapter to several gentlemen, and can report from their examinations a few corrections on what has preceded.

Prof. Quimby reports, upon reëxamining his note books, that 118 feet should be added to the height of the Shaker barn, Canterbury (see pp. 242, 277); and that 28 feet should be added to the height of North Putney hill, Hopkinton (see pp. 242, 280). The heights of Mts. Moose and Cuba, when calculated from Observatory hill, Hanover, "come out within ten or fifteen feet" of what they are given on page 242. All these altitudes on page 242 have been reduced from the original figures given to us, to agree with the known heights of Kearsarge and the state house, by subtracting 55 feet. This has not been done in the case of Mts. Pequawket and Pleasant (p. 280), the figures being given as stated in the published Coast Survey reports.

Many persons may desire that these altitudes should have been much more numerous. Others might have been given, but I did not think it desirable further to encroach upon the text, especially as the contour map will give a general idea of the altitude of every foot of land in the state.

I should have been glad to reproduce Prof. Guyot's figures, as obtained by the mercurial barometer, for comparison with those of the Geodetic Connection survey. It has been done only in a few cases on page 280. His barometrical figures are usually nearly as reliable as those obtained by the measurement of vertical angles. I have altered his figures of the heights of mountains in Warren, page 281, measured on the slope of Moosilauke with a pocket level, and communicated privately to William Little, by the difference between the barometrical and trigonometrical heights of Moosilauke. I have been disappointed in not receiving from Prof. Guyot answers to several questions about his measurements, sent with the proofs of this chapter. Hence the reference to "note beyond," on page 275, has no significance.

R. S. Howe, engineer of the Northern Railroad, suggests the addition of the following statement to the end of the second paragraph on page 249: "and an efficient means of noticing the orographical and other physical peculiarities of the state, and placing within reach of the medical profession a record that may enable and induce professional men in different localities to observe, record, and contrast the influence of elevation, if it has any, on health and disease. Hitherto, latitude and longitude have been the chief and almost the only conditions modifying climate that have been taken into account in considering the influences on health; but the observations of physicians and travellers present facts suggesting that altitude, to some extent, controls the type of diseases."

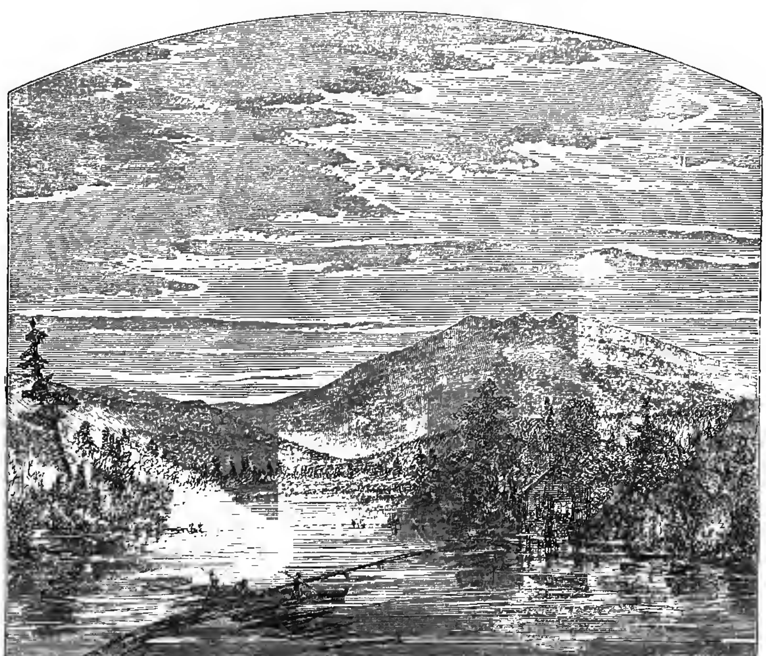

Fig. 44.—WHITE MOUNTAINS, FROM BRIDGE IN BERLIN, NEAR MILAN.

CHAPTER XI.

RIVER SYSTEMS OF NEW HAMPSHIRE.

BY WARREN UPHAM.

OF the entire area of New Hampshire it is estimated that one sixth part is covered with water. Fifteen hundred streams are delineated on the various county and other maps; and numerous lakes and ponds are scattered over the entire state. The object of this chapter will be to present a description of our different hydrographic divisions; and to consider the influence of the position, physical features, and climate of our state upon the distribution and character of its rivers and lakes.

New Hampshire is divided into five hydrographic districts, which are drained by the Connecticut, Merrimack, Androscoggin, Saco, and Piscataqua rivers. None of these river systems is wholly comprised within the limits of the state. The description of these districts should embrace both the principal river, with tributaries and lakes, and also the area drained, or river basin. Of the rivers, the features which require notice are the direction and extent of their course, their volume, and their slope or rapidity of descent. Of the drainage basins, the particulars to be noted are position, area, elevation, and proportion of surface covered by forest. The relations of rain-fall and temperature, being nearly uniform in the different portions of the state, are left to be considered with the other general conditions on which the hydrographic character of the state depends.

Boundaries of Hydrographic Basins.

Connecticut River. The main water-shed of the state, separating the waters of the Connecticut from those of the Androscoggin, Saco, and Merrimack, commences at the Canadian boundary five miles south-west of Crown monument, and three miles east of Third lake.* Its course is first south-east to Mts. Abbott and Carmel, thence south-west nearly to the southern border of Second lake, thence south to Magalloway mountain, and then south-west to Mt. Pisgah. It next bends more to the west, and reaches its farthest limit just west of the Diamond ponds in the eastern part of Stewartstown; thence it runs south-east to Dixville notch, thence a little east of south, through Millsfield, Dummer, and Milan, to a point about three miles north-west of Berlin falls. Here it bends to the south-west, passing along the mountain ridges in Randolph, then south-east to Mts. Jefferson and Washington, then south-west along this range to Mt. Clinton and the Notch. Thence it extends nearly west over the Twin mountains and Lafayette to Cannon mountain in Franconia; thence it turns south-west, passing over Mt. Kinsman, through the west part of Lincoln and near the boundary between Woodstock and Benton, to Moosilauke, from which it descends to the Oliverian notch in the north part of Warren. It then passes to the mountains in the north-west corner of this township, and thence south-westerly over Ore hill and through the south-east corner of Piermont to Mt. Cuba in the east part of Orford. From this it extends south-east to Cardigan mountain in Orange, dividing Dorchester by a diagonal line. It next turns south-west to Orange summit, on the Northern Railroad; thence it extends nearly south through the west part of Grafton and the north-east part of Springfield, passing into New London between Little Sunapee lake and Pleasant pond, thence bending south-west to within a half mile of Sunapee lake at its north-east extremity. This line next passes over the high ridge in the north-west corner of Sutton, thence south-west into Newbury, again coming within about a half mile of Sunapee lake at its southern end, and thence west to Sunapee mountain. From this the water-shed line follows the highlands, which extend south, nearly through the centres of Washington, Stoddard, Nelson, and Dublin, to Monadnock mountain. Thence it passes

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* See, also, p. 218.

a little east of south through Jaffrey, and partly through Rindge; it then turns north-east to Kidder mountain in the south-west corner of Temple, from which it extends south-west across the west part of New Ipswich to the Massachusetts line.

Altitudes along this principal water-shed of the state have been already given on pp. 209–211. From the course of this line it will be seen that the drainage area of the Connecticut river in New Hampshire is of comparatively uniform width, the water-shed averaging about sixteen miles distant from the river. The point of least width is in the north part of Orford, where it is contracted to five miles. The farthest part drained by this river system from New Hampshire is in New Ipswich, thirty miles from the Connecticut at its nearest point. The length of this basin in New Hampshire, in a direct line, is 185 miles.

Merrimack River, Eastern Water-shed. The line dividing the Merrimack basin from those of the Saco and Piscataqua begins about three miles south-west from the White Mountain notch, and runs nearly south over Willey, Carrigain, Tripyramid, Black, and Sandwich mountains, passing through Elkins's grant, the east part of Waterville, and the west part of Sandwich, to a point about a mile and a half north of Squam lake. Here it turns to the east, passing between Red Hill and Bear Camp ponds, thence south-east to Ossipee mountain in the east part of Moultonborough, thence through the east part of Tuftonborough to a point one half mile south of Upper Beech pond, around which it passes, running north-east to a point about one mile east of Water Village.

The place where this water-shed line approaches nearest to Lake Winnipiseogee is west of Upper Beech pond, one of its bays being here three miles distant. The farthest point that is drained into Winnipiseogee is that last named, being on the north side of Batson pond, seven miles from the lake.

Thence it follows nearly the north-east and south-east boundaries of Wolfeborough to Mt. Delight, passing within one mile of Smith's pond. Thence it extends south through the west part of Brookfield, over Copple Crown mountain, thence south-west through New Durham, nearly to Downing's mills, passing one mile south-east from Merry-meeting lake. Here the course again turns south to the west corner of Farmington, then south-east three miles to the Blue Hills range, which it follows


HYDROGRAPHIC
BASINS.
EXPLANATION.
CONNECTICUT.
MERRIMACK.
ANDROSCOGGIN.
SACO.
PISCATAQUA.
ATLANTIC BORDER.

across Strafford. Thence it extends south through Northwood to Saddleback mountain, thence a little south of west through Deerfield to Allenstown line, near Shingle ponds. Thence it passes on a curve through the west and south portions of Candia to Patten's hill. From this point it follows nearly the west and south boundary lines of Chester, next passing through the north part of Hampstead, between Island pond and Phillips pond, Sandown, thence north-east to near the Town hall in Danville, thence east through Kingston village,—the large ponds of Kingston being tributary to Powwow river on the south. Thence its course is south-east, passing through East Kingston village, and the south-west corner of Kensington, to the Massachusetts line, near the boundary between South Hampton and Seabrook.

The width of the Merrimack basin at its source, measured from Mt. Willey to Cannon or Profile mountain, is about fifteen miles. This increases to the section from Brookfield across Winnipiseogee lake to Orange, which is forty-three miles. Thence southward to Manchester it remains very nearly the same. From near Manchester this area widens on the east, bending in the direction of the river's mouth at Newburyport. Its greatest width in New Hampshire, from the west line of Seabrook to Monadnock mountain, is sixty miles. Its length, from Profile lake south to the Massachusetts line, is ninety-eight miles.

Androscoggin River. The water-shed between the Androscoggin and Saco extends from the summit of Mt. Washington to Pinkham notch, passing between Huntington's and Tuckerman's ravines, and thence nearly east, through Bean's purchase to the Maine line. Its course is across high mountain ranges, which extend north and south, and are covered with unbroken forest.

By reference to our hydrographic map, it will be seen that Coös county, north from Mt. Washington, is nearly equally divided between the Connecticut and Androscoggin basins. The latter, as far as included in New Hampshire, averages about eleven miles in width, being sixteen miles wide at its southern end, and fifteen at the sources of the Swift Diamond river, while it is narrowed to almost nothing at Mt. Carmel. The length of this hydrographic district, measured on the eastern boundary of the state, is seventy-one miles.

Saco River. The water-shed between the Saco and Piscataqua starts

from the east line of the Merrimack basin in Wolfeborough, and passes east through the north corner of Brookfield and near the centre of Wakefield to the Maine line, which it crosses between Balch and East ponds.

Nearly the whole of Carroll county is comprised within the Saco basin, which has in New Hampshire an average width of about eighteen miles, and a length, measured on our eastern boundary, of forty-six miles.

Piscataqua River. The south-east boundary of this district starts from the Merrimack river water-shed at East Kingston, and passes east through Kensington village, thence north-east through the east corner of Exeter, thence east and north-east through North Hampton to Breakfast hill between Greenland and Rye, from which it passes north-east through Rye to Odiorne's point at the south side of the mouth of the Piscataqua.

This basin includes in New Hampshire nearly all of Strafford and half of Rockingham counties, averaging about eighteen miles in width, and forty-five miles in length, measured from Wakefield to East Kingston. From the sources of the Pawtuccaway river to the mouth of the Piscataqua is thirty miles, from which point the width of this district diminishes northward, being ten miles at Farmington.

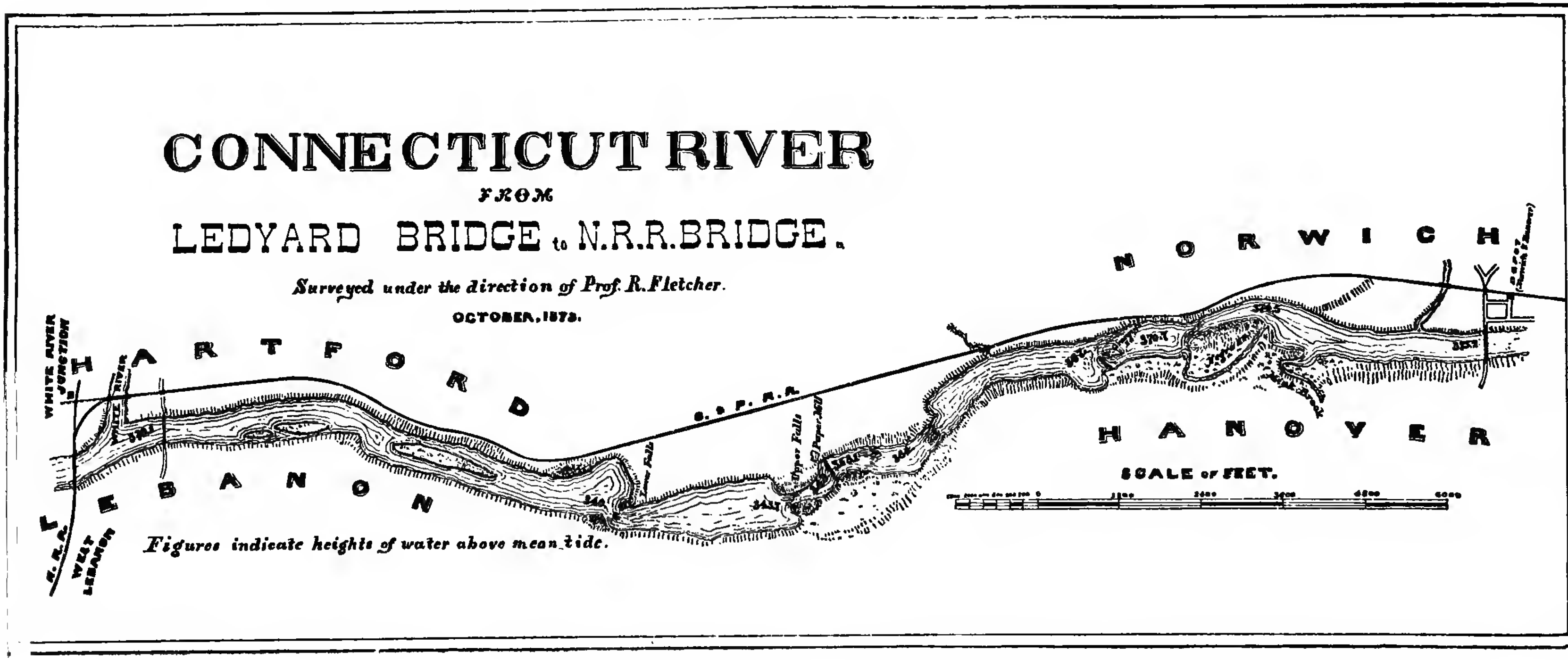
Hampton Falls River, &c. The portion of New Hampshire south of the last described water-shed and east from East Kingston and South Hampton, forming our sea-coast slope, is drained directly into the ocean by Hampton Falls and Taylor's rivers and numerous smaller streams, not being included in either of the principal hydrographic districts adjacent.

The most distant point of this area from the ocean is in the south-east corner of Exeter, six miles from the coast. Its length from Odiorne's point to the Massachusetts line is thirteen miles.

The accompanying map shows the dimensions and relative areas of these hydrographic basins, and the course of water-shed lines.

Connecticut River System.

The basin of the Connecticut comprises about 3,060 square miles in New Hampshire, or three tenths of the area of the state. The line of low water on the west side of this river forms the boundary between this state and Vermont; and Hall's stream, the third considerable tributary from the right below its source, continues this boundary between our state and the province of Quebec. In addition to this area drained from



CONNECTICUT RIVER
FROM
LEDYARD BRIDGE to N.R.R.BRIDGE.
Surveyed under the direction of Prof. R. Fletcher.
OCTOBER, 1873.
WHITE RIVER JUNCTION
WHITE RIVER
HARTFORD
LEBANON
N. R. R.
WEST LEBANON
Figures indicate heights of water above mean tide.
Lower Falls
Upper Falls
Paper Mill
NORWICH
HANOVER
DEPOT (Norwich & Hanover)
SCALE OF FEET.
1000
2000
3000
4000
5000

New Hampshire, the Connecticut basin embraces about 3,750 square miles in Vermont, or four tenths of that state, making a total of more than 6,800 square miles in both states, nearly all of which contributes to the water-power of this river along our western border.

The general course of the head stream of the Connecticut river, passing through Second and Connecticut lakes to the mouth of Hall's stream, is S. 60° W.,* being a distance of twenty-five miles from its farthest sources in a direct line, and of twenty-eight miles from Third lake, following the course of the river. The descent along this distance is comparatively rapid, with few and narrow intervals. The surface of the country is moderately hilly but not rugged, and more than nine-tenths is still covered with the original forest.

From the mouth of Hall's stream to the head of Fifteen-miles falls in Dalton, the general course is S. 13° W., a distance of forty-two miles in a direct line, or forty-six miles, if we follow the principal bends in the river. Along this whole distance are the fertile intervals of the upper Connecticut valley, varying from one half mile to a mile in width. The surface back from the immediate river valley rises in bold hills or mountains, and fully four fifths of its area is covered by forest.

From the head of Fifteen-miles falls, near the mouth of John's river, to the mouth of the Passumpsic, the course of the Connecticut is S. 70° W., being a distance of eighteen miles in a direct line, or about twenty, following the stream. Opposite to this portion of the river, on the east and south-east, is the elevated mountain region of the state. Here the descent is rapid, and the surface more broken than in any other part of the course of this river. Its direction is also bent to the west along this distance, beyond which the general course of the upper is again followed in the lower valley, with but slight deviation, almost to the Massachusetts line.

This course from the mouth of the Passumpsic to Brattleborough is S. 16° W., a distance of 103 miles in a straight line, or 107 by the course of the river. Along this distance the river intervals and terraces of the valley usually extend from one half to a mile and a half in width on each side of the river, but are occasionally interrupted on one or both sides by encroaching ranges of hills. The water-shed which separates this portion of the Connecticut basin from that of the Merrimack, every-

* All courses here given are referred to the true meridian.

where reaches a considerable elevation, and frequently is marked by mountains. The slope on the west from opposite Haverhill extends to the Green Mountain range of Vermont, its greatest width being at the sources of White river, which are thirty-eight miles from the nearest point of the Connecticut, and forty-two miles from the mouth of White river. In the northern half of Vermont, a large area east of this mountain range is drained into Lake Champlain and the St. Lawrence.

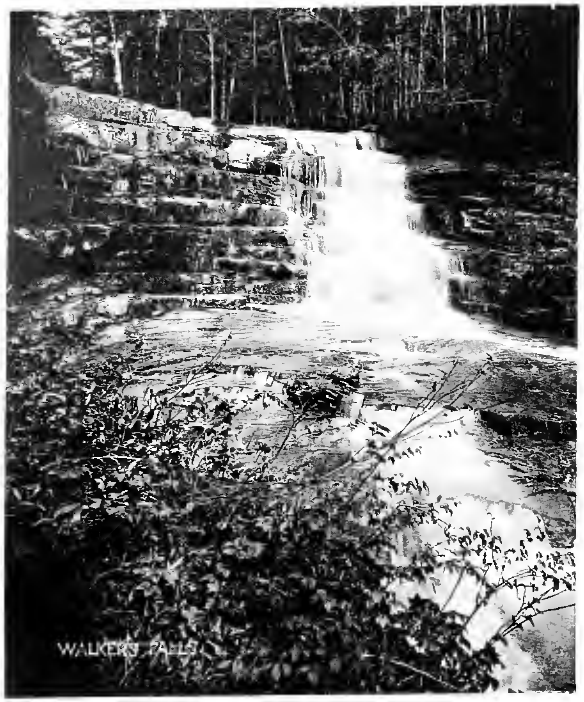
South from Brattleborough the Connecticut, for the remaining ten miles in New Hampshire, has a general direction S. 25° E., again resuming nearly its former course after crossing the Massachusetts line. Of this basin, from the mouth of the Passumpsic, probably two thirds are covered with forest.

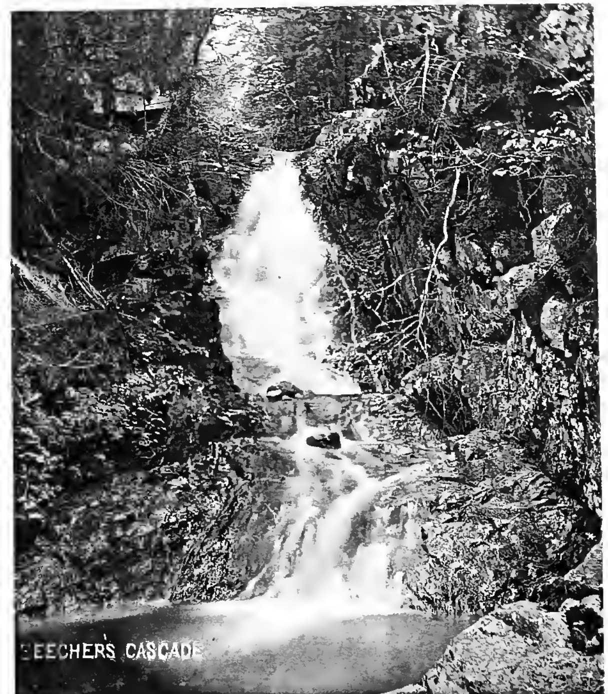
The entire length of the Connecticut from Third lake, following its principal bends along our western border to the Massachusetts line, is 211 miles.

Altitudes at various points, with distances from Third lake, are given in the following

Table of Heights of Connecticut River.

	Distance from Third lake.	Height above sea.
Third lake, ¾ square mile in area,		2058 feet.
Second lake, 1¾ square miles in area,	5 miles.	1852 "
Connecticut lake, 3 square miles in area,	10 "	1618 "
At West Stewartstown,	30 "	1035 "
North Stratford,	49 "	885 "
Lancaster,	67 "	832 "
Head of Fifteen-miles falls,	74 "	830 "
Upper Waterford,	84 "	674 "
Lower Waterford,	86 "	643 "
Foot of McIndoe's falls,	98 "	432 "
Wells River,	105 "	407 "
Orford,	123 "	380 "
Ledyard bridge, Hanover,	137 "	375 "
White River Junction,	141 "	339 "
Mouth of Quechee river,	146 "	323 "
Windsor,	155 "	304 "
Beaver meadow, Charlestown,	169 "	289 "
Head of Bellows falls,	181 "	283 "
Foot of Bellows falls,	181½ "	234 "
Westmoreland,	191 "	219 "
Mouth of Ashuelot river,	208 "	206 "


WALKER'S FALLS


BEECHER'S CASCADE

The principal branches of this river system in New Hampshire are arranged in the following table in their order, beginning at its source,—their lengths, and the areas and altitudes of lakes and ponds connected, being stated approximately.

Tributaries of Connecticut River.

	Course.	Length in miles.	Lakes and Ponds.	Area in square miles.	Altitude in feet above sea.
ON WEST SIDE.			[Note. See Connecticut and upper lakes in Table of Heights preceding.]		
Perry stream, Pittsburg,	S. S. W.	12			
Indian stream, Pittsburg,	S. S. W.	15			
Hall's stream, Pittsburg,	S. S. W.	16			
ON EAST SIDE.					
Deadwater stream, Clarksville,	N. N. W.	7			
Bishop's brook, Stewartstown,	N. W.	7			
Mohawk river, Colebrook,	W.	10			
Sims stream, Columbia,	N. W.	8			
Bog brook, Stratford,	S. W.	8			
Upper Ammonoosuc, Northumberland,	N. & W.	28	Trio ponds, Odell,	0.4	2490
			Pond of Safety, Randolph,	0.1	1973
			Head pond, Berlin,	0.4	1075
			Percy pond, Stark,	0.5	1040
			Potter's pond, Stark,	0.5	1025
Israel's river, Lancaster,	N. W.	15			
John's river, Dalton,	N. W.	12	Cherry pond, Jefferson,	0.3	1200
			Island pond, Whitefield,	0.25	1050
			Long pond, Whitefield,	0.25	950
Lower Ammonoosuc, Bath,	W. & S. W.	36	Echo lake, Franconia,		1926
Oliverian brook, Haverhill,	N. W.	8			
Eastman's brook, Piermont,	W.	7	Great pond, Piermont,	0.6	1150
Mascomy river, Lebanon,	S. & W.	23	Norris pond, Dorchester,	0.6	1250
			Hart's pond, Canaan,	0.75	975
			Crystal lake, Enfield,	0.6	1050
			Mascomy lake, Enfield,	1.5	750
Sugar river, Claremont,	W.	17	Little Sunapee lake, New London.	0.66	
			Sunapee lake,	11.2	1090–1103
			Spectacle pond, Sunapee,		1123
Little Sugar river, N. Charlestown,	W.	8			
Cold river, Walpole,	S. W.	17	Cold pond, Acworth,	0.4	1300
			Warren pond, Alstead,	0.5	550
Partridge brook, Westmoreland,	N. W.	6	Spofford lake, Chesterfield,	1.0	738
Ashuelot river, Hinsdale,	S. W.	40	Breed pond, Nelson,	0.7	1250
			Woodward pond, Roxbury,	0.3	1150
			Swanzey pond, Swanzey,	0.2	

The principal tributaries which the Connecticut receives from Vermont are Nulhegan river at Brunswick, Passumpsic river at Barnet, Wells river at Newbury, Wait's river at Bradford, Pompanoosuc at Norwich, White river at White River Junction, Quechee river at Hartland, Black river at Springfield, Williams river at Rockingham, and West river at Brattleborough. A portion of this basin in Vermont is drained by the Deerfield river, passing into Massachusetts, while in New Hampshire the head waters of Miller's river include portions of Richmond, Fitzwilliam, and Rindge.

Merrimack River System.

The Merrimack river receives this name south from Franklin, where the Pemigewasset and Winnipiseogee rivers unite. Its area of drainage in New Hampshire is about 3,825 square miles, or four tenths of the state. This river system comprises the central portion of New Hampshire, including our principal lake region, and has its source in the centre of the White Mountains. Our largest cities have grown up along the Merrimack, and its name has become associated, like those of Winnipiseogee lake and Mt. Washington, with all descriptions of the Granite State.

From its source in Franconia to the Massachusetts line, its general direction is S. 8° E., being 100 miles in a direct course, or 105 miles following the principal bends in the river. The first thirty-eight miles of this distance is nearly S. 5° E.; it then bends nearly west four miles to Bristol village, and this is the only considerable deviation from its general course. From this point to the mouth of the Suncook river, a distance of thirty-three miles, it runs nearly S. 20° E., thence a distance of thirty miles its course is about S. 2° E. to the Massachusetts line. After passing beyond the limits of the state, the Merrimack bends to the north-east, the boundary line south of Rockingham county being parallel with its course and three miles distant. Its total length is about 144 miles.

The upper part of the Pemigewasset valley is narrow, and closely bordered on both sides by mountain ranges. The intervals begin in Thornton and Campton. The high sandy plains, which are characteristic of this valley southward, commence at New Hampton. The alluvial area along this river is much wider than on the Connecticut, and the hills rise less abruptly upon either side. The proportion of this basin covered by forest is probably nine tenths north of Plymouth, and two thirds southward.

Winnipiseogee Lake. The hydrographic basin of Winnipiseogee lake comprises about 350 square miles. Its waters flow into the Merrimack, though the general level of the country would seem to ally it with the waters of the Saco or Cochecho valley. The height of the divide separating it from the latter is only seventy-two feet at the lowest place.

The lake is quite irregular in form. Its general course is S. 25° E., with several long bays or arms. On the south is Alton bay, eight or ten

miles long, which resembles a fiörd more than any of the other arms. On the south-east is Wolfeborough bay, in close connection with Smith's pond. On the north-east are two branches into Moultonborough. On the north-west is the expanse known as Meredith bay. The western shore is comparatively straight from Meredith Village to Alton Bay village. The hills about the lake are steeper than the average in other parts of the state.

The length of the lake proper is 19 miles. The breadth at the widest part is 8¼ miles. Its area is 69.8 square miles. If Long bay, which is properly an expansion of the outlet, be added, the area becomes 71.8 square miles.

The lake abounds in islands. Their number, large and small together, is two hundred and seventy-four. The water is remarkably pure, but shallow. No soundings have been made, but no part is likely to be over two hundred feet deep. By the dam at the outlet of this lake a depth of six feet is made available for the use of manufacturing companies in the dry season. The top of this dam is 502 feet above mean tide.

Areas about Lake Winnipiseogee, as given on the Lake Company's map.

Area of Lake Winnipiseogee, including islands, . .	2,176,362,817	square feet.
Area of the islands, ...	227,313,357	"
Water in Lake Winnipiseogee, ...	1,949,049,466	"
or, 69 square miles, 531 acres, and 3.03 square rods.		
Area of Long bay, including islands, ...	55,041,789	"
Area of the islands, ...	362,131	"
Water in Long bay, ...	54,679,658	"
or, 1 square mile, 615 acres, 43.56 square rods.		
Total area of water, ...	2,003,729,124	"
or, 71 square miles, 559 acres, and 46.39 square rods.		

Distance around Lake Winnipiseogee, ...	895,730 feet.
Distance around Long bay, ...	69,905 feet.
Total, ...	965,635 feet, or 182.89 miles.

Islands.

Number of islands in Lake Winnipiseogee, of greater area than 1000 acres,	1
" " " " of greater area than 500 and less than 1000 acres,	2
" " " " " " 100 " 500 "	7

Number of islands in Lake Winnipiseogee, brought forward, ...	10
No. islands in L. Winnipiseogee, of greater area than 50 and less than 100 acres,	6
" " " " " 10 " 50 "	25
" " " of less area than 10 acres, ...	226
Number of islands in Lake Winnipiseogee, ...	267
" " Long bay, ...	7
Total number of islands, ...	274

Table of Heights of Merrimack River.

	Distance from Profile lake.	Height above sea.
Profile lake, Franconia, ...		1950 feet.
Pemigewasset river, at mouth of East Branch, ...	9 miles.	1350 "
Pemigewasset river at Plymouth, ...	27 "	455 "
Winnipiseogee lake, 71.8 square miles, ...		496–502 "
Merrimack river at Franklin,*	52 "	275 "
Merrimack river at Concord, ...	69 "	225 "
Amoskeag dam, Manchester, ...	85 "	179 "
At foot of Amoskeag falls, ...	85½ "	121 "
At mouth of Nashua river, ...	101 "	93 "
Dam at Pawtucket falls, Lowell,†	112 "	87 "
Essex Company's dam, Lawrence,†	122 "	39 "

Tributaries of Merrimack River.

	Course.	Length in miles.	LAKES AND PONDS.	Area in square miles.	Altitude in feet above sea.
ON WEST SIDE.					
			Upper Baker pond, Orford, . .	0.3	
Baker's river, Plymouth, ...	S. E.	23	Lower Baker pond, Wentworth,	0.3	
			Stinson pond, Rumney, . .	0.6	990
Newfound river, Bristol, . . .	S.	2	Newfound lake, . .	8.0	597
Smith's river, Bristol, .	E.	15			
Webster Lake brook, Franklin, . . .	S. E.	5	Highland lake, Andover, . .	0.33	
			Webster lake, Franklin, . . .	0.6	446
			Great pond, Boscawen, . . .	0.33	
			Long pond, Boscawen, . . .	0.4	
			Pleasant pond, New London, .	1.0	
			Kezar pond, Sutton, ...	0.25	
			Long pond, Sutton, ...	0.3	
			Todd pond, Newbury, . .	0.3	677
			Bradford pond, Bradford, .	0.8	665
			Clement pond, Hopkinton, . .	0.2	
Contoocook river, Fisherville, . . .	N. E.	45	Contention pond, Hillsborough,	0.3	
			Loon pond, Hillsborough, . .	0.33	
			Island pond, Washington,	0.6	1248
			Stacy pond, Stoddard, . . .	0.7	
			Spoonwood pond, Nelson, . .	0.25	
			Long pond, Nelson and Hancock,	1.2	1338
			North pond, Harrisville, .	0.2	1218
			Harrisville pond, ...		1334
			Pollard pond, Greenfield, .	0.3	

* Corrected from statement on page 286. † Furnished by J. B. Francis, of Lowell.

Tributaries of Merrimack River—Continued.

	Course.	Length in miles.	LAKES AND PONDS.	Area in square miles.	Altitude in feet above sea.
Piscataquog river, Manchester,	E.	20	Mt. William pond, Weare,	0.2	
			Gregg's pond, Deering,	0.4	
			Haunted pond, Francestown,	0.3	
Souhegan river, Merrimack,	N. E. & E.	25	Baboosic pond, Amherst,	0.6	
Nashua river, Nashua,	E. & N. E.	35			
ON EAST SIDE.					
East Branch, Woodstock,	W.	14			
Mad river, Campton,	S. W.	15	Greeley pond, Elkins grant,	0.25	1815
Beebe river, Campton,	W.	10			
Squam river, Ashland,	S. W.	3	Squam lake,	15.6	510
			Little Squam lake,	0.95	510
Winnipiseogee river, Franklin,	S. W.	12	Winnipiseogee lake,	71.8	502
			Merrymeeting lake, New Durham,	3.7	589
			Smith's pond, Wolfeborough,	4.5	540
			Dishwater pond, Tuftonborough,	0.6	
			Red Hill pond, Sandwich,	0.5	
			Long pond, Center Harbor,	0.6	505
			Wukawan lake, Meredith,	1.0	542
			Wickwas pond, Meredith,	0.45	
			Round bay, Laconia,	0.5	
			Great and Sanbornton bays,	6.8	
Soucook river, Pembroke,	S.	15	Rocky Pond, Gilmanton,	0.35	
Suncook river, Allenstown,	S. W	20	Place's pond, Alton,	0.25	799
			Young's pond, Gilmanton,	0.4	
			Lougee pond, Gilmanton,	0.6	622
			Halfmoon pond, Barnstead,	0.4	
			Suncook pond, Barnstead,	1.2	
			Wild Goose pond, Pittsfield,	0.5	
			Little Suncook pond, Northwood,	0.75	512
			Pleasant pond, Northwood,	0.75	
Brown's brook, Hooksett,	N. W.	6	Sawyer pond, Hooksett,	0.3	429
			Lakin's pond, Hooksett,	0.4	307
Cohas brook, Manchester,	S. W.	4	Massabesic lake, Auburn & Manchester,	4.0	256
Beaver brook, Dracut, Mass.,	S.	18	Beaver pond, Derry,	0.3	
			Cobbett's pond, Windham,	0.6	
Spiggot river, Lawrence, Mass.,	S.	13	Wash pond, Hampstead,	0.25	
			Island pond, Hampstead,	0.75	
			Policy pond, Salem,	0.7	
Powwow river, Amesbury, Mass.,	S. E.	15	Country pond, Kingston,	0.75	
			Great pond, Kingston,	0.33	

The Contoocook river of this system is the largest tributary river in New Hampshire. Its area of drainage on the south-east is narrow. From the north-west side it receives Blackwater and Warner rivers in Hopkinton, North Branch, near the north line of Antrim, and Nubanusit river at Peterborough.

Androscoggin River System.

The Androscoggin river is entitled to this name southward from the confluence of the waters of the Magalloway and those of the range of lakes at a point about one mile from Umbagog lake, and three miles north-east from Errol dam. The area drained by this river in New

Hampshire is about 775 square miles, or one twelfth of the state. About 900 square miles from Maine are also drained by this river through New Hampshire.

The course of the Androscoggin from Umbagog lake is first a little south of west about five miles to the mouth of Clear stream, from which its general course is S. 5° W. to the mouth of Moose river at Gorham, a distance of thirty-three miles, following the bends of the river. Along this portion of its course the Androscoggin flows almost directly towards the highest and most massive range of the White Mountains, approaching within ten miles of the summit of Mt. Washington. At Gorham, this barrier turns the river sharply to the east, a distance of nine miles, carrying it into the state of Maine.

The length of the Magalloway, from its source in Pittsburg, near the most northern point of New Hampshire, to its mouth, is thirty-three miles in a direct line, or thirty-nine miles, following the principal bends in the stream. A large portion of this river is nearly level and very meandering, although its general course is nearly straight. The total length of river from Magalloway lake, the source of this stream, to the point where the Androscoggin enters Maine, is eighty-six miles.

The most distant point in Maine drained by the range of lakes is about forty miles in a direct line from the junction of these waters with the Magalloway. We copy, from Wells's *Water Power of Maine*, the following statement of the area, altitude, and amount of storage as reservoirs, of the

RANGE OF LAKES IN MAINE.

	Approx. area in square miles.		Height in feet above sea.	Present storage in feet.
Umbagog,	18		1256	14
Welokenebacook,	11		1456	12
Molechunkemunk,	10		1456	12
Mooseluckmaguntic,	21	77	1486	14
Cupsuptic,	3		1486	14
Rangeley,	14		1511	4

Our eastern boundary runs across Umbagog lake, dividing it in nearly equal portions to the two states. The length of this lake is about eleven miles, the north portion being bent east into Maine. By the dam in Errol, four miles below its mouth, the outlet is made navigable for a


BERLIN FALLS

steamboat to that point, and the waters of the Magalloway are made to contribute to the reservoir storage of the lake.

Almost the entire area drained by the range of lakes and the Magalloway is unbroken forest, which also covers nine tenths of this basin southward in New Hampshire.

Table of Heights of Androscoggin River.

	Distance from Magalloway lake.	Height above sea.
Magalloway lake,		2225 feet.
Parmachena lake, 3 square miles,	13 miles.	1600 "
Umbagog lake,	39 "	1256 "
At head of Berlin falls,	72 "	1048 "
At Maine line,	86 "	690 "

Tributaries of Androscoggin River.

	Course.	Length, in miles.	LAKES AND PONDS.	Area in square miles.	Altitude in feet above sea.
ON WEST SIDE.					
Swift Diamond river, College grant,	E.	15	Diamond pond, Stewartstown,	0.4	
Clear stream, Errol,	S. E.	10	Mosquito pond, Millsfield,	0.45	1270
			Wentworth pond, Wentworth's Location,	0.4	
			Aker's pond, Errol,	0.5	
Moose river, Gorham,	E.	8			
Peabody river, Gorham,	N. E.	9			
ON EAST SIDE.					
Chickwalnipy river, Milan,	W.	8	Burnside pond, Success,	1.0	

Saco River System.

The area drained by this system in New Hampshire is about 850 square miles, or one eleventh of the state.

The distance in a straight line from the head of the Saco beyond the White Mountain notch to its point of crossing the Maine line is about twenty-five miles, the direction being nearly south-east. Following the course of the river, this distance is about thirty-four miles. The first eleven miles it runs a little east of south, with high mountains bending in steep and gracefully curved slopes to form its valley. The next nine miles extend nearly east, through the level intervals of Bartlett to the

mouths of Ellis river and East Branch. The river then turns nearly south eight miles to the mouth of Swift river in Conway, from which point it flows east six miles to Maine line.

The southern portion of this basin in New Hampshire is drained by the Ossipee river, which passes into Maine. A large part of this area about Ossipee lake is comparatively level, consisting of sandy plains. The proportion of forest in the whole basin is probably about three fourths.

Table of Heights of Saco River.

	Distance from source.	Height above sea.
Pond at source, near gate of White Mountain notch,		1880 feet.
At Willey house,	2.6 miles.	1300 "
Mt. Crawford house,	8.5 "	975 "
Line between Hart's location and Bartlett,	12.5 "	745 "
Mouth of Rocky Branch,	18 "	560 "
Mouth of Ellis river,	20 "	511 "
Portsmouth, Great Falls & Conway Railroad crossing,	25 "	446 "
Portland & Ogdensburg R. R. crossing, Conway Centre,	30 "	412 "
Ossipee lake, 7 square miles,		408 "

Tributaries of Saco River.

	Course.	Length in miles.	LAKES AND PONDS.	Area in square miles.	Altitude in feet above sea.
ON EAST SIDE.					
Mt. Washington river, Hart's Location,	S. S. W.	7			
Ellis river, Bartlett,	S. S. E.	12			
East Branch, Bartlett,	S. S. W.	12	Mountain pond, Chatham,	0.25	
ON WEST SIDE.					
Swift river, Conway,	E.	15	Walker pond, Conway,	1.8	
Ossipee river, Cornish, Me.,	E.	15	Ossipee lake,	7.0	408
			Six-mile pond, Madison,	2.5	456
			Chocorua lake, Tamworth,	0.4	
			Bear Camp pond, Sandwich,	0.4	
			Dan Hole pond, Tuftonborough,	0.65	
			Pine River pond, Wakefield,	0.7	
			Province pond, Effingham,	1.8	

The length of Ossipee river is given from Iron Works falls at the mouth of Ossipee lake. The Bear Camp and Pine rivers, outlets of ponds bearing the same names, are the principal tributaries to this lake. From Iron Works falls to the source of Bear Camp river is twenty miles.

PISCATAQUA RIVER SYSTEM.

The Piscataqua river is formed by the union of the Cochecho and Salmon Falls rivers at Dover. The second, in its whole length, with the Piscataqua, constitutes a part of our eastern state boundary. The area of this basin in New Hampshire,—those towns on the coast which drain directly into the ocean being also included in this measurement,—is about 825 square miles, or nearly one eleventh of the state.

From East pond, the source of Salmon Falls river, to the mouth of the Piscataqua, is nearly thirty-eight miles in a straight line, the course being S. 20° E. By the course of the river this distance is thirty-nine miles, the length of Salmon Falls river being twenty-eight miles, and of the Piscataqua, from the junction of this river with the Cochecho, eleven miles. The course of Salmon Falls river in the first twelve miles is nearly south. The next thirteen miles to Salmon Falls is nearly south-east; thence the course is south seven miles to the mouth of Great bay, thence south-east about seven miles to the ocean, three miles below Portsmouth.

This river is affected by tide to Dover and South Berwick. Between the township of Durham and those of Greenland and Newington is a wide tidal basin, which receives the waters of several rivers. Upon Exeter or Squamscot river, the largest of these, tide extends to the village of Exeter. The area of this estuary, south-west from Dover point, including Little and Great bays, is about nine square miles. From Dover point to Portsmouth the Piscataqua is about half a mile wide. Below this city it contains numerous islands, the largest of which constitutes the township of Newcastle.

The section of New Hampshire drained by this river system is, for the most part, level. Probably about one third is covered with forest.

TABLE OF HEIGHTS OF PISCATAQUA RIVER.

	Distance from East pond.	Height above sea.
East pond, Wakefield, 2.9 square miles (Wells)		499 feet.
Horn pond, " 0.4 " " "	1 mile,	479 "
Three ponds, Milton, 1.4 " "	9 miles,	400 "
Great Falls, top of dam,	22 "	166 "
Bow lake, Strafford, 1.7 " "		515 "

Tributaries of Piscataqua River.

	Course.	Length in miles.	Lakes and Ponds.	Area in square miles.	Altitude in feet above sea.
TO SALMON FALLS RIVER.					
Branch river, Milton, ...	S. E.	12	Cook's pond, Brookfield, . .	0.4	
			Lovell's pond, Wakefield, . .	1.0	
			Reservoir, Middleton, . .	0.9	
			BY ISINGLASS RIVER.		
Cochecho river, Dover, . . .	S. E.	25	Bow lake, Strafford, . . .	1.7	515
			Ayer's pond, Barrington, .	0.6	
			Long pond, Barrington, . . .	0.2	
			Nippo pond, Barrington,	0.2	
TO GREAT BAY.					
Bellamy river, Dover, ...	E. S. E.	16	Dodge's pond, Barrington, .	0.2	
			Swain's pond, Barrington, . .	0.25	
Oyster river, Durham, . . .	E.	10	Wheelwright's pond, Lee, . . .	0.4	131
			Pawtuccaway pond, Nottingham,	4.5	
Lamprey river, Newmarket, . .	E.	20	Mendam's pond, Barrington, .	0.4	
			Jones pond, Raymond, .	0.25	258
Exeter river, South Newmarket, .	E. N. E.	22	Phillips pond, Sandown, . . .	0.25	215

The altitudes of numerous other ponds not here mentioned, heights of rivers on lines of railroad surveys and where crossed by geological sections, and the elevation of prominent points on water-sheds, given in the preceding chapter, need not be repeated here. For the purpose of comparison we annex a few heights of lakes in other states.

	Height above sea.
Moosehead lake, Maine, ...	1023 feet.
Sebago lake, "	251 "
Willoughby lake, Vermont, ...	1161 "
Memphremagog lake, "	634 "
Lake Champlain, "	93 "
Lake Superior, ...	630 "
Itasca lake, Minnesota, ...	1575 "

Effect of Geographic and Continental Position.

If we inquire into the causes which influence the hydrographic character of New Hampshire, we find that the situation of our state gives us favorable conditions of climate, producing well-watered fields for the farmer, and abundant water-power for manufacturing industry.

New Hampshire is situated between 42° 40′ and 45° 18′ 23″ north latitude, and between 70° 37′ and 72° 37′ longitude west from Green-

wich. In consequence of this *geographic position*, almost equidistant between the equator and the pole, the amount of evaporation in New Hampshire is only that due to a moderate temperature; the moisture of the soil is not burned away by long continued and excessive heat, nor are the sources of water supply wholly cut off by long and uninterrupted cold. For the same reason the winds are variable, not constant as within the tropics, but coming throughout the year from every quarter of the compass, rarely for more than two or three days from the same point, bringing heat and cold, moisture and dryness, in succession. It follows also from this geographic position, that the precipitation of moisture is non-periodic. It occurs in the form of either rain or snow at all seasons, tending to make the volume of streams constant throughout the year. Its fall is usually gentle, often occupying several days for the deposition of a single inch of water. On this account sudden and great inundations are of rare occurrence. It is generally attended, also, with a protracted continuance of cloud, fog, or mist, which lessens evaporation, and, in consequence, increases the volume to be removed by drainage.

The *continental position* of New Hampshire has the further effect to produce a larger rainfall and a smaller amount of evaporation than the average for this latitude. It is situated on the coast, and is constantly visited, therefore, by currents of air directly from the ocean, tending to produce a more equable temperature, increased rainfall, and a humid atmosphere. It lies directly in the current of the south-west winds from the Gulf of Mexico. This great inland sea is noted for its remarkably high temperature, to which it presents an evaporating surface of 800,000 square miles in area. The prevailing course of our storms being from the west and south-west, it is to a very large extent from this source that their vapor is derived. This is precipitated upon us in our so-called north-easterly storms, the moisture being brought in large measure by an upper current whose course is opposite to that experienced below.

This deposition, also, is relatively more abundant here than farther south, because of the colder currents of air which these storms encounter here, after uniting with which their combined capacity for retaining moisture becomes greatly diminished, the excess necessarily falling in the form of rain. The whole circulation of the Arctic ocean, including all the waters which are brought in by the currents through Behring's strait,

and from the north coast of Europe, after being reduced to a very low temperature and loaded with vast masses of ice, is poured in a constant stream by the east coast of Greenland, by Baffin's bay, and the straits north of Hudson's bay directly upon the shores of Labrador and Newfoundland, and is afterwards carried as a cold inshore drift along our coast. Our north-east and east winds are, in consequence, of low temperature, producing an excessive rainfall by their meeting with the warmer south-west currents of our prevailing storms. By another remarkable oceanic current, known as the Gulf stream, enormous volumes of water, of almost tropical temperature, are brought into sudden contact with this polar current off the coast of Newfoundland. The warm atmosphere overhanging the Gulf stream is saturated with moisture, and on meeting the cold atmosphere of the polar current this is condensed, covering the Grand Banks, the Gulf of St. Lawrence, and the adjacent ocean and land with thick and comparatively constant fogs. These vapors are brought over our state by east and north-east winds, sometimes remaining for days, or, with some intervals, for weeks together, especially in the latter part of summer. The cool fogs of the dog days throughout New England, which are in marked contrast with the sultry heat of that season in the interior, are derived from this source, or in part from a similar condensation of the moisture of southerly winds blowing from the Gulf stream across the cold ocean current along our shores. The obvious effect of these fogs, occurring most notably in the midst of the protracted heat of summer, when streams tend to run lowest, is greatly to diminish the evaporating power of the sun and reserve a large proportion of the rainfall for removal by drainage.

The conditions of our climate, resulting from geographic and continental position, are thus such as to give increased volume and unusual constancy to our streams.

Physical Character of New Hampshire as related to Water-Power.

The consideration of the hydrographic features of the state is of especial interest, as exhibiting the extent and value of its water-power. Our river systems are hardly more important as a part of the physical geography than they have already become in their relation to the industries

and wealth of the state. A general view of the nature of these resources will cause us to see utility as well as beauty in our river and lake scenery.

Among the physical characteristics of the state which affect the amount and availability of its water-power, we should first consider its *geological structure.* Here the most noticeable feature in this relation is the ability of the ledges to resist decomposition. This is the prevailing character of very ancient rock formations. They resist the wearing action of water, breaking the course of streams with numerous falls and abrupt rapids, and maintaining the uneven condition of river beds, which renders water-power capable of use. The importance of this feature will be rightly estimated by a comparison with the prevailing form of river channel in the south-western portion of the United States, where the rivers find their way by an almost subterranean passage through cañons many miles in length and hundreds of feet deep, while the parched and sterile country is rendered impassable by their yawning chasms. This character of our rocks also reduces the amount of water, which is absorbed through crevices and fissures in strata, and which, in a season of drouth, is lifted to the surface, and burned away by evaporation. It is also of peculiar importance in relation to the water-retaining capacity of our lakes and ponds, these being in the majority of cases underlaid and walled in with impervious rock. The same consideration insures the reliability of artificial reservoirs wherever natural slopes of land admit of their construction.

It is also to be noticed that the disintegrated material, which almost everywhere overlies the solid rock, is comparatively shallow. The sides and bed of nearly all our streams, at points where falls or rapids exist, are rock-set and rock-bound, though apparently covered with earth. Ravages of river beds and diversions of river courses, which in alluvial districts are productive of much inconvenience, or even of serious losses, are on this account very rare. Canals and race-ways can be constructed in permanent material, and when once completed need no repairs. Mills and accompanying structures can be planted on ledge bottom, and thus defy the treacherous undermining of deep currents. A permanent dam can be built at almost any point where the slope of a stream is sufficient to produce a rapid; so that, dam succeeding dam, the whole descent of the stream may be utilized, the damage from flowage or from wear upon

the banks being as a general statement very small. To this comparative shallowness of earth, and consequent prominence of the underlying rock, we also owe the large amount of water-power which occurs on our rivers in the lower portion of their course. Were the geological character of our sea-coast the same as that of the Southern states, our rivers near the sea would be worthless for water-power, having deepened their valleys through the loose strata so as to be affected far inland by the rise of the tide, while their size is such that they would be of little value for purposes of navigation in comparison with the power which they now furnish for our manufactures.

The character of the surface of New Hampshire should also be considered in its effect upon the water-power. Under this head the most important inquiry is in regard to the *contour or general elevation of the state* in different sections, including the arrangement and character of its slopes, and the distinguishing features of its mountains, drainage basins, and river valleys.

From the tables of altitudes already given in this chapter, it is seen that Connecticut lake, the principal source of our largest river, exceeds 1600 feet above the level of the sea. The descent of this river from this point to the north line of Massachusetts is more than 1400 feet. This total descent is distributed over the entire distance of its course, furnishing a succession of valuable water-powers often equal to those which have caused the rapid building up of such cities as Manchester, Lowell, and Lawrence. Although no considerable distance along this river is destitute of sufficient descent to produce upon improvement a valuable water-power, it is not intended to convey the idea that the rate of fall is nearly uniform along its entire course. By recurrence to the list of altitudes, it will be seen that its descent in the first 17 miles, to the bridge between West Stewartstown and Canaan, Vt., is about 600 feet; in the next 44 miles, to the mouth of John's river in Dalton, the descent is about 200 feet; in the next 24 miles its descent is again rapid, amounting to about 400 feet, the course of the river being transferred, with a westerly offset by the rapids of Fifteen-miles falls, from the Upper to the Lower Connecticut valley. From the northern continuation of the latter valley it receives the waters of the Passumpsic. In the remaining 113 miles of its course along our western border, its descent is about 230 feet, which

is divided into successive falls and rapids, separated by only a few miles from each other, along this entire distance. This river leaves the state at a height of 200 feet above sea.

The water-power of this river at one of its principal falls, about two miles north of White River Junction, is illustrated by the annexed plate, prepared by Mr. J. T. Woodbury, of the Thayer Department of Civil Engineering, Dartmouth college. He states that the amount of flow of the Connecticut at Ledyard bridge on May 4, 1874, was 3,498,636 gallons per minute, and estimates that in the driest season the flow might be reduced to one eighth of this amount. A dam 10.8 feet above present surface at the head of the falls, one fourth mile above the paper mill, flows back to this bridge, and gives a fall of 31½ feet at a distance of half a mile. A canal now exists on the New Hampshire side, formerly used for the river navigation, in which a depth of ten feet is secured by this dam. This canal passes through 450 feet of hornblende schist, and would require enlargement. On the Vermont side a canal can be constructed of any desired length, passing through the common terrace formation of the river.

East and south-east from the point where the Connecticut river enters its lower valley is the extended mountain region of New Hampshire. From the wide interval on the Lower Ammonoosuc river, seven miles south-west from Mt. Washington, to the place where that river empties into the Connecticut, is a descent of about 1150 feet. The lowest point of the water-shed, dividing the waters of the Lower Ammonoosuc from those of the Saco, has an elevation of over 1900 feet above the sea. Here is an area of 1300 square miles, or one seventh of the area of the whole state, thickly set with mountains which vary in height from 3000 to 6000 feet above the level of the sea, the bottoms of its valleys varying from 1000 to 2000 feet in altitude. These mountains constitute a group in the general form of an oblique parallelogram, having its corners in Bethlehem, Shelburne, Conway, and Warren. Of course any such rigid boundaries must be imperfect; the south line should be bent farther south at the middle to include the high mountains of Sandwich; the mountains of Orford, and those on the opposite side of the river in Vermont, seem to be the south-western extension of this central group, while in a north-eastern direction it is continued into the state of Maine.

The most elevated portion of that state, extending north-easterly across it a little north of its centre, covered with numerous lakes and isolated mountains, is the virtual extension of the more elevated area of our White Mountain region. This area is not, however, continuous to Connecticut lake, from which it is separated by the drainage basin of the Upper Ammonoosuc and the deep valley of the Androscoggin. The general direction of mountain chains of the Appalachian system is thus seen, although the arrangement of our mountains departs from the general type of the great Alleghanian ranges, as seen in Vermont and Massachusetts, Pennsylvania, Virginia, and North Carolina. Instead of occurring as one continuous chain, our mountains form a group, made up of several parallel ridges or short chains, extending north and south, the highest summits of these successive ridges, in order from south-west to north-east, being Moosilauke, Kinsman, Lafayette, Twin mountain, Mt. Washington, and Mt. Carter. East and west ridges and scattered peaks also occur, especially near the south and south-east limits of the group.

The relation which this great mountain region holds to the water-power of the state is three-fold. It places one seventh of our state at a greater elevation above the sea than any other section of New England, giving a correspondingly increased amount of water-power in the descent of its streams. From this elevated mountain area a gradual slope extends, varied by transverse ranges of hills and outcropping ledges in the channels of rivers, producing falls or rapids to within a few miles of the ocean. This increased amount and convenient distribution of water-power cannot be too highly estimated. The available power of the Merrimack river alone has been stated by good authority to be double that of all France.

The influence of mountains in producing an increased rainfall is well known. Observations in the mountain districts of northern England show a rainfall frequently three or four times that of the lowland around. The average rainfall at Edinburgh, 200 feet above the sea, in three successive years, was 30 inches; in the Pentland hills, a few miles south, at 700 feet above sea, it was 37.4 inches; at 900 feet above sea, 49.2 inches. Sufficient observations have never been taken to determine the rainfall of our mountain region, and special circumstances may very much reduce this proportion of increase, but it cannot be doubted that a much

larger amount of rain and snow is collected here than upon the same area in any other part of New Hampshire.* This is effected by the refrigeration of currents of air, coming in contact with the relatively cool mountain ridges, their moisture being thereby condensed and precipitated as rain. The clustered arrangement of our mountains and their disposition in numerous short ranges, transverse to the direction of our prevailing storms, would tend to increase their influence in this respect.

The third consideration to be noticed is, that this whole area is heavily wooded, with the small exception of such alpine summits as have an elevation more than 4000 feet above the sea. This condition prevents the very rapid drainage which would otherwise produce overwhelming freshets, sweeping all before them, after which the streams would dwindle to mere rills, worthless for water-power. By this clothing of forest, however, the large rainfall of this area is stored up, as in a sponge, and gradually given forth, producing in our mountain-fed streams one of the principal resources of our water-power when most needed in the drouth of summer. This effect of forests is due to several causes. A great amount of decaying vegetable materials and mosses, which become saturated with rain, everywhere covers the ground in our forests, and the earth is loosened through which tree roots have forced their passage, giving water a chance to penetrate it,—from both which conditions its volume, when in surplus, is husbanded against too sudden removal. Thus the forest acts as a capacious reservoir for retaining the water as it falls. A further office is the protection of the ground from the parching heat of the sun, and from the similar effect of drying winds, producing a permanence and constancy in the springs on which the summer volume of our streams mainly depends. Forests also check the waste of winter snow as well as of summer rain. Patches of ice and snow may be found, as late as early June, lying here and there in the defiles and ravines of our northern woods, and even late in summer in secluded mountain glens, saturating the ground as they melt, and sending off streamlets to the nearest brook or river. It will be seen that our forests are, to an important extent, so situated as to exercise their characteristic influence

*The rainfall at the summit of Mt. Washington during the first year of observation was 55 inches, against an average annual rainfall varying from 35 to 46 inches in other portions of the state (p. 135).

upon the constancy of water-power to the best advantage, namely, upon the mountain region of the state. Thus located, it is certain that they will remain for a long time substantially as they now are, deprived indeed of their heavier timber, but still dense woods; so that this effect, which is unquestionably of great importance in a consideration of our water-power, will be at the same time permanent. (See p. 123.)

The source of the main stream of the Merrimack river,—better known north from its confluence with the Winnipiseogee under the name Pemigewasset,—is Profile lake, situated in the midst of the Franconia ranges, at the very foot of the mountain wall from whose top hang the jutting rocks that make up the profile of the Old Man of the Mountains. This little mountain lake is about 1950 feet above the sea. The first considerable tributary which the Pemigewasset receives is the East Branch, which drains a wholly uninhabited basin 150 square miles in area, bounded, and in the middle almost crossed, by ranges of high mountains. The descent of this river, to the mouth of the East Branch, in a distance of nine miles, is about 600 feet. From this point to Plymouth, a distance of 18 miles, it descends about 900 feet; in the next 25 miles to Franklin, where it receives the Winnipiseogee, it descends about 175 feet, the descent from Lake Winnipiseogee, 500 feet above the sea, being 225 feet. From this place to the southern boundary of the state, a distance of 53 miles, its descent is about 185 feet, the height of the Merrimack at the average stage of water at this point being 90 feet above the sea. The water-power of this distance is located, as on the Connecticut, at numerous falls, separated from each other by intervals of a few miles each, affording unimproved sites for manufacturing cities as favorable as any already occupied. The tributaries of this river are also specially important for their water-power.

North-east of the White Mountains a large amount of water-power is furnished by the Androscoggin river, which has its sources and the lower portion of its course in the state of Maine. Being connected with a chain of lakes which can be employed as immense reservoirs,—for which they are already used to obtain a sufficient supply of water at the last part of the log-driving season,—this river can be made perfectly reliable for water-power in the driest summer. The sources of this river, in both its upper drainage areas of the range of lakes and Magalloway river, are from the high water-shed ridge which forms the north-west boundary of

Maine, having an altitude of nearly 3000 feet above the sea. The upper portion of the range of lakes is 1500 feet in altitude; Umbagog lake, about 1250 feet. At the east line of New Hampshire the Androscoggin is about 700 feet above the sea. The great value of this very reliable water-power, for the manufacture of lumber,—of which there is an almost inexhaustible supply on the lakes and streams above,—cannot fail to be appreciated and more fully employed.

Although the south-eastern portion of the state along the coast is comparatively level and of small altitude, the descent of its rivers is gradual, in consequence of the projecting strata of solid rock, being broken by falls to within a short distance of the sea, and affording very valuable facilities for manufacturing. The water-shed between the lower part of the Merrimack in New Hampshire, and the section drained north-easterly toward the Piscataqua, is very low. By reference to our tables of altitudes, it will be seen that the highest point on the Nashua & Rochester Railroad is only 345 feet above the sea. Phillips pond, the head of Exeter river, has an altitude of 215 feet. The sources of Cochecho and Salmon Falls rivers are among the hills at the south-east end of Lake Winnipiseogee,—East pond, at the head of Salmon Falls river, having the same altitude with this lake, namely, 500 feet above the sea.

The drainage areas on either side of our river valleys are specially favorable for the provision of a large and comparatively constant water supply. With the exception of our mountains, already noticed in their relation to our water-power, the narrow intervals and alluvial plains in the valleys of our largest rivers, and the level portions of eastern Rockingham county, our whole state is covered with irregularly scattered ridges of hills. The rainfall is gathered into our streams and lakes without the large waste from evaporation and infiltration which takes place upon comparatively level water-sheds, such as those of a large portion of the West. At the same time, the surface being only moderately broken, consisting of wide swells of hilly country to a large extent covered with forest, the drainage from rains is not too sudden, so as to turn our rivers into torrents which cannot be used in passing, and leave nothing behind. This variety of local elevations and depressions is of still further importance, since it affords room for the natural formation of invaluable storage basins of reserved water-power.

No feature in the physical geography of a country is of greater importance in a consideration of its water-power than the number, size, and distribution of its *lakes and ponds*, and the adaptation of its surface for the construction of artificial reservoirs, and for increasing the capacity of those which have been naturally formed. The importance of this appears when it is remembered that water-power is suitable for extensive manufacturing, where large amounts of capital are invested, only in proportion as it is constant and reliable at all seasons of the year. It may be employed for local convenience and by small establishments, even though it be variable at different seasons, and its use wholly suspended during the driest portion of the year; but it is only when a constant supply of water-power can be depended upon, that it is capable of being advantageously employed by large manufacturing corporations,—the greater cheapness of water-power, as compared with steam-power, being more than counter-balanced if business must be interrupted and capital lie idle because of the failure of streams. By lakes, ponds, and artificial reservoirs, the surplus of heavy rains and of snow melting is stored up in the season of excess against the season of dearth. Our natural reservoirs are of a capacity, too, which man would not presume to imitate by artificial constructions, being also provided almost free of cost, and capable of being put to actual use with insignificant outlay.

In our climate the need of a reserved water supply is likely to be experienced at two seasons of drouth,—in midsummer, and, to a less degree, in midwinter. Although the amount of rainfall for the different quarters of the year is nearly equal, the increased heat of summer and consequent evaporation, together with the fact that our summer rainfall is to a considerable extent from showers, and subject to greater variableness than that of any other season, usually cause our streams to reach their lowest point at some time during the last part of summer,—the period of drouth being in some years protracted, in others scarcely noticeable or wholly wanting. In winter, on the other hand, precipitation takes place largely in the form of snow. The ground itself, in all its upper stratum, is also frozen solid, and yields but small contributions to the streams. The value of reservoirs to provide a supply against the contingency of want at these seasons can scarcely be over-estimated. By these the regulation of the water supply is under the control of the consumer, and

not dependent upon the caprices of a variable climate, which, by proving unfavorable, would bring great inconvenience and loss.

Lakes and reservoirs are also of great value in lessening the frequency and violence of freshets. By their storage of water, in floods and snow-meltings, they reduce the volume of streams at these times, causing a comparatively moderate rise of surface. Manufacturing establishments, built upon rivers subject to heavy floods, have to be constructed of great strength and with much care to withstand the water, and, if so placed as to be secure against the overflow of freshets, are often too high for advantageous use at the ordinary stage of water. The equability of volume in our rivers is not less important as insuring the security of property invested, than it is in making the investment certain of a profitable return.

A further consideration of importance is, that the water of lakes and ponds is so warm in winter, that mills near them and fed by them experience no trouble from the formation of ice about their gate-ways and wheels, even during the severest cold. Only their upper strata sink below 39° in midwinter, the deeper portion being so protected by the non-conducting mantle of ice, that during the longest winter the general temperature remains far above the freezing point.

The altitude of our lakes and ponds above the sea should also be noticed. The supply which they are capable of furnishing in a drouth is of equal benefit to all the water-powers situated below them on their pathway to the sea. This enables a large number of interested companies to enter into combination for the improvement of these natural storage basins, most of which are so situated that the lowering of their outlets, or the erection of dams at a comparatively small outlay, would double or treble their value. The expense of such improvements would be divided among a large number, each of whom would receive the full advantage of the increased water supply. A large number of small ponds will also be improved for the same object by proprietors on their outlets, thereby increasing at the same time the capacity of the larger powers below.

The average depth of reserve, that with a reasonable outlay could be retained upon the surface of our lakes and ponds for use during the dry season in each year, would probably not be less than eight feet, while the natural low run of the streams would be more than doubled. Indeed,

the proportion of reservoir water used by large manufactories is in many cases eighty or ninety per cent. of the whole amount during the drier season of the year. It is easy to see, therefore, how great an advantage our water-power has in comparison with any which is obliged to rely upon the natural flow of the streams, or, if supplied with reservoirs at all, has to depend on artificial constructions of comparatively great cost and limited capacity.

Rainfall and Evaporation.

A previous chapter of this report has been devoted to the general consideration of the climate of New Hampshire: reference must be made to this for statistics and meteorological tables. It is proposed to consider briefly in this place the *rainfall* and *temperature* of the state, as related to the volume and constancy of our rivers.

The rainfall of New Hampshire, as we have already noticed, is considerably in excess of the normal amount. From a comparison of the records of the Smithsonian Institution, it appears that the average rainfall for the same latitude westward to the Missouri river is not more than three fourths of the average amount which we receive. A like comparison with places south of us along the Atlantic slope shows that their annual rainfall also is less than that of New Hampshire. The difference, however, is small; but the comparison is remarkable, since these places are entitled upon general principles to a considerably larger rainfall than our state. This deviation from the general law of distribution becomes intelligible when the local conditions are taken into account, namely, the cold ocean currents north-east of us and along our shores, the consequent low temperature, and its influence upon the storms which sweep over us. The precipitation of moisture throughout the year is also remarkably uniform, the total amount being almost equally divided between the four seasons. The practical consequence of this distribution of rainfall is, that our state enjoys comparative security from the two great obstacles to the successful employment of water-power, freshet and drouth.

These favorable conditions are still further promoted by our temperature. In no other part of the Northern Hemisphere, except north-eastern China, does the isothermal line, which represents the mean temperature of our state, sink so near to the equator,—that is, our average temper-

ature is unusually low for the latitude. The line of the same average temperature for the year crosses Europe several hundred miles farther north, corresponding to the mouth of the St. Lawrence and the southern coast of Labrador. Thus while New Hampshire cannot be declared to be cold in respect to comfortable habitableness and capacity of vegetable production, it is so in a relative sense, and as compared with other countries no further removed towards the poles.

This is mainly caused by the cold oceanic current already referred to, which the Arctic sea pours forth upon the north-eastern shores of our continent. This effect is exerted on so grand a scale that the whole north-east portion of North America is constituted a geographic region of relatively low temperature. The focus of this district is at the north-east corner of Hudson's bay, its relative deficiency of heat being 13°. The temperature of all adjacent regions is lower than that due to the latitude in proportion to their proximity to this point. Thus, at Quebec the deficiency is stated by Wells as nearly 7°, and at New York, 4°; throughout New Hampshire it is therefore about 5°.5,—that is, our mean temperature is what might be expected were our geographic position five degrees farther north. The temperature of Europe, on the other hand, is much warmer than would be expected for the latitude, owing to the warm current of the Gulf Stream, which is constantly pouring upon its shores.

This comparatively low temperature of our state largely increases the volume of its streams. This is effected, first, by the condensation of a large amount of moisture from the warm south and south-west winds, inducing a more abundant rainfall than could be looked for in our latitude and upon the lee side of the continent; and, secondly, by diminishing the waste of water from evaporation, preserving consequently a larger proportion for removal by rivers. Having already noticed the conditions which are concerned in the first of these results, it remains to speak here of the relation of evaporation to water-power, and the modification of this influence from our comparatively low temperature.

Of the total rainfall of the state, probably sixty per cent. is removed by evaporation from our surface before it reaches the sea. In the case of various reservoirs, where an exact measurement of this proportion could be taken, the evaporation from the drainage area has been found

to vary from fifty to sixty per cent. of the total rainfall. From England and Ireland the amount of evaporation is estimated as two thirds; from the Ohio and upper Mississippi river basins, three fourths; from the basins of the Missouri, Arkansas, and Red rivers, five sixths of the whole rainfall.* The larger proportion west of the Mississippi is due to the prevalence of winds already reduced to dryness by passage over mountain ranges, and still more inclined by the increased temperature of this region to absorb rather than impart moisture. In the Ohio and upper Mississippi basins the mean temperature is higher than with us, and the air more drying throughout the year; the surface, also, is far less favorable for drainage than in our own state. In a comparison with the British Isles, it is to be noted that our mean annual temperature is several degrees lower than theirs, our winters sealed by frost against evaporation while theirs are open, and our surfaces to a much larger extent forest clad, producing probably with us a considerably lower proportion of evaporation.

The tendency to evaporation is of course less in proportion as the winds which reach our area are charged with moisture. Our position on the coast is favorable in this regard. It is not, however, the actual amount of moisture which air contains that renders it moist, but the relation between that amount and the amount which is capable of being held in suspension. Although the south-west storms which sweep over us, laden with the evaporation of the Mexican gulf, have become deprived of much of their moisture before reaching us, they are still as thoroughly saturated as at their start, having become cooled, and consequently capable of holding less moisture in the same proportion as they have given it up. As we have seen, this cooling process becomes more rapid as these winds reach us, on account of our unusually low temperature, giving them great relative humidity, with the results of increased rainfall and lessened evaporation. Thus the effect of our temperature is to give us relatively moist instead of drying winds, making the loss by evaporation from the surface a comparatively low proportion.

The average summer temperature of New Hampshire is several degrees lower than that of places of the same latitude farther west, while a still greater difference is exhibited in a comparison with the middle and

* Wells's *Water Power of Maine*, 1869, p. 52.

southern states. Our chances of water dearth occasioned by summer heat are thus greatly diminished as compared with other sections of the country.

Our winter temperature is more nearly like that of the same latitude westward, being indeed less severe, the neighborhood of the sea having the effect to lessen the extremes of our temperature, which is lower in summer, and on an average for the year, but nearly the same in winter. Our mean winter temperature, however, falls considerably below the freezing point of water. The ground, therefore, with its contained water, tends to freeze solid to a considerable depth, thereby lessening the supply of streams. Much of the surface water upon the drainage sheds throughout this season is changed to ice. The precipitation also is mainly in the form of snow. But these circumstances, which seem to threaten water dearth, never act to their full extent in combination to reduce river supply. When a large depth of snow falls the ground does not freeze deeply, and continues therefore to give forth the reserved abundance of the autumn rains. Nor does the severity of the temperature often last many weeks without such intervals as admit of rains and the thawing of part of the accumulated snow, with sufficient time for drainage, by which the water supply is reinforced and the lakes and reservoirs filled. Thus, while our streams tend to run low in winter, they are still almost always prevented from reaching so low a point as in the heat of summer.*

The frequent thaws of winter also prevent the accumulation of snow from being wholly reserved for the melting of spring. The disappearance of the snow remaining at that season, however, sometimes attended with heavy rains, usually produces the highest stage of water for the year. A few of the conditions which modify this result deserve to be considered. During the winter the snow generally becomes solidified, especially in its lower portions, almost to ice, and in this form it disappears but slowly before the advancing heat of the year. The ground, even if frozen before snowfall, is usually thawed out beneath the snow of winter, and becomes a reservoir for a large amount of water, thus retarding the discharge into the rivers. For these reasons, the accumulations of winter go off with

* Reference to charts illustrating isothermal lines and rainfall will show that the Merrimack valley is the warmest area in the state, and, also, that it receives the most rain. Combining with these the constancy of flow caused by the large lake reservoirs, and it is clear that the Merrimack river is superior to the Connecticut, if not to any stream in the country, for its capabilities for driving machinery. C. H. H.

less swelling of the streams than is experienced farther south and in the interior, where the depth of snow is less, but where the spring heat comes on more suddenly, and without the moderating influence of cold sea winds.

The effect of summer temperature, also, although sufficient to produce the lowest run in our streams for the year, is yet far different from that experienced in many portions of our country. No such thing is known in New Hampshire as the drying up of streams, draining hundreds of square miles of territory, into chains of half-stagnant pools, their beds turned into wastes of fissured, sun-baked mud, strewn with the stumps and driftwood of freshets, leaving long bridges stretching across dry land, where, at the spring flood, a torrent twenty feet deep fills the entire channel.

In conclusion, it appears that the temperature of the state, on the whole, influences very favorably both the volume and constancy of our rivers. The mean for the year is comparatively low, and the loss from evaporation is therefore of necessity comparatively small. Our relative advantage in this respect is also greatest in the abatement of the drouth of summer, which everywhere fixes the limit of the capacity of water-power.

Fig. 45.—OLD MAN OF THE MOUNTAINS.

CHAPTER XII.

THE DISTRIBUTION OF INSECTS IN NEW HAMPSHIRE.

BY SAMUEL H. SCUDDER.

I. General Considerations.

PROBABLY no state in the Union presents so striking a variety in its animal life as New Hampshire. Its northern and southern portions belong to distinct continental faunas; above the forest growth of its colder region rise some of the highest elevations east of the Rocky Mountains, and these bleak altitudes support a vegetation and an assemblage of animals intimately resembling those of Labrador and Greenland, while sixty miles to the south flourish animals characteristic of subtropical climes.

In the northern hemisphere, rivers flowing south always exert an influence upon the character of the inhabitants upon its banks; and the Connecticut, although navigable but fifty miles, is no exception to the rule. At its southern extremity it reaches a warm coast and a latitude where numerous insects occur, whose true metropolis is found in the Carolinas and Floridas. Many of these, following the course of the river, with its warm, moist banks, penetrate into the heart of the country; some are found in central Massachusetts, a few in southern Vermont and New Hampshire, and one or two are found even in the latitude of the White Mountains. It is therefore especially interesting to consider the distribution of a few groups of insects in New Hampshire.

In 1854, Prof. L. Agassiz made the first attempt* to divide North America into several zoölogical areas; and, on a rude map accompanying his sketch, he draws a line in an east-westerly direction, which passes through New Hampshire. The two great regions thus separated he names the Canadian and Alleghanian faunas.

In 1859, Dr. J. L. LeConte divided the United States into a number of "entomological provinces;"† and the "northern" and "middle" provinces of his "Atlantic district" were separated by a line which passed through the southern half of New Hampshire.

In 1863, Prof. A. E. Verrill also pointed out that the dividing line of the Canadian and Alleghanian faunas cut New Hampshire in two,‡ and three years later he defined the limits more exactly as "coincident with a line which shall indicate a mean temperature of 50° Fahrenheit during the months of April, May, and June;" and, in describing its course, says,—"It passes south of Moosehead and Umbagog lakes, but rises somewhat northward along the Androscoggin valley, thence it passes southward of the White Mountains, through the vicinity of Conway, N. H. It bends northward again up the Connecticut valley as far as Craftsbury, Vt., where the mean temperature is 50° 91." ‖

Mr. J. A. Allen has recently discussed the areas of the faunas of eastern North America; and, in his description of the northern boundary of the Alleghanian fauna, says the line "follows the northern boundaries of the lowlands through southern Maine and southern New Hampshire. In the Connecticut valley it rises farther to the northward, and, in its southern descent, skirts the eastern base of the Green Mountains." §

Both of these latter writers base their conclusions upon the study of birds during breeding season, as first suggested by Prof. Verrill, in 1866, in the paper from which we have quoted, and where he further writes,—"From this remarkable coincidence between this system of lines of temperature of the months of spring and early summer, with what had been already observed in the actual distribution of birds, we must necessarily infer

* Nott and Gibbon: *Types of Mankind*, p. lxxviii, and map.

† *The Coleoptera of Kansas and Eastern New Mexico.* Smiths. Contr. 4to, 1859.

‡ "The Adirondack region of New York, the northern parts of Vermont and New Hampshire, including most of the higher parts of the Green Mountains and all of the White Mountains, and even the summits of the higher Alleghanies, will be included in the Canadian fauna." *Proc. Ess. Inst.*, iii, 138.

‖ *Proc. Bost. Soc. Nat. Hist.*, x, 260.

§ *Bull. Mus. Comp. Zoöl.*, ii, 395 (1871).

that they are chiefly influenced, so far as latitude is concerned, by the temperature of the breeding season . . . ; whether a similar law controls the distribution of mammalia, reptiles, insects, etc., can only be determined by further investigation."

Since insects are not regularly migratory animals; as several generations frequently succeed each other during a single season; and, as the winter is passed in very various conditions, we can hardly expect their distribution to follow exactly that of birds. Various causes may modify unequally the distribution of insects belonging to a certain group: too intense cold in our arctic winters; the lack of snow during a less severe season; too excessive heat or too long a drouth in midsummer; or, too sudden changes of temperature at critical periods. Taking our butterflies only, they may be found at every season of the year, even in midwinter, of one species or another, in every stage of existence, from the egg, through all the larval periods and the chrysalis, to the imago. The distribution of butterflies is therefore much more complicated than that of birds, whose early stages are always passed in comparatively warm weather, under the guardianship of the mother; and, if more than one brood appears during a season, the second is only the produce of the same pair that raised the first.

It is nevertheless true that the distribution of insects over continental areas coincides in a remarkable way with that of birds. The northern limits of the Alleghanian fauna, as laid down by Verrill, agree very fairly with the northern boundary of the belt colored blue on Plate B; and this probably indicates pretty accurately the southern limit of *Cyclopides Mandan* and the northern limit of *Megisto Eurytus*, *Grapta comma*, *Argynnis Cybele*, *A. Aphrodite*, and *Euphyes Metacomet.* It may be questioned, however, whether, as far as butterflies are concerned, this can really be considered the northern limit of the Alleghanian fauna. If we trace upon a map of the state the northern limits of the several Alleghanian butterflies and the southern limits of the Canadian, they will be found to mingle in a broad belt of country, which includes all the colored portions of Plate B. The northernmost Alleghanian and southernmost Canadian species gradually decrease in numbers away from their metropolis, and become confined to increasingly lower or higher altitudes in this belt, according as they are Alleghanian or Canadian forms.

Mr. Allen's location of the dividing line between the Alleghanian and Canadian faunas, though rather vaguely stated, seems to correspond better with the distribution of butterflies, though it is perhaps still too far north; and I have colored a narrow band red on Plate B, which will indicate more exactly the limitation which seems to accord best with the facts at my command. This band, striking the Maine boundary opposite the lower extremity of Lake Winnipiseogee, runs in a south-westerly direction nearly parallel with the coast line of Maine, until it reaches the vicinity of the Monadnock mountain (Hillsborough county), and then turns sharply upward and strikes the Connecticut river at the highlands about Claremont. In the neighborhood of this band (sometimes closely confined to it) are the southern limits of such Canadian butterflies as *Minois Alope*, and the northern limits of such Alleghanian butterflies as *Basilarchia Astyanax, Grapta interrogationis, Vanessa Huntera, Speyeria Idalia, Pterourus Troilus, Erynnis Juvenalis, Anthomaster Leonardus,* and *Limochores Manataaqua;* other species, including northern types like *Grapta Faunas* and *Argynnis Atlantis*, and southern types, such as *Epargyreus Tityrus* and *Pamphila Sassacus*, find their southern or northern limits, as the case may be, within other portions of the broad blue belt; while, again, some Alleghanian species, such as *Achalarus Lycidas, Pholisora Catullus, Amblyscirtes vialis, Ocytes Metea*, and *Poanes Massasoit*, find their northern limit at the southern boundary of this belt; and some Canadian species, such as *Argus Eurydice* and *Aglais Milberti*, find at this same point their southern limit.

It is plain that somewhere within this blue belt the dividing line between the Canadian and Alleghanian faunas must be drawn; and it will probably prove difficult to discover any more exact boundary than this, for we should certainly expect an interdigitation of forms peculiar to the two faunas over some common area; and it is only by direct study of the comparative abundance or rarity of very many species of animals within this broad belt that any more exact limitation can be obtained. The local zoölogists of New Hampshire can render science an important service by a careful record of such facts in as many distinct localities as possible; only it is essential that such observations be continued through several successive seasons (best, for a decade), for the comparative abundance of any one species, in any one locality, depends upon a variable


DISTRIBUTION OF INSECTS IN NEW HAMPSHIRE
BY S. H. SCUDDER. PLATE B.
EXPLANATION.
Canadian Fauna, including the Sub-Alpine and Alpine.
Alleghanian Fauna.
Common meeting ground of Canadian and Alleghanian species.
Boundary between Canadian and Alleghanian Faunæ.

climate, the antagonism of other insects, and many other causes still unknown.

It may be well to enter with more detail upon the probable limits of the belt colored blue on Plate B. At the north, it enters New Hampshire from Maine near the range of hills lying east of Pinkham's notch, and comes from the direction of Bethel or Norway, Me. That the latter town lies near the boundary between the Alleghanian and Canadian faunas is evident from the extensive collections of Messrs. Verrill and Smith. From this point it runs between Bartlett and Conway toward Plymouth, passing just north of the latter town, following up Baker's river toward the Connecticut, and only crossing the latter stream at some distance above Wells river. At the north, on either side of the White Mountains, the Alleghanian fauna extends along the river bottoms of the Androscoggin, the Connecticut, and even the Ammonoosuc, but too narrowly to be traced upon our map. Less is known about the southern boundary of the band at its eastern extremity, but it must enter the state between Dover and the sea, and it continues in a nearly straight line through Milford to Warwick, Mass. Here it turns upward and toward the Connecticut, crossing the river certainly above Brattleborough, Vt., and perhaps as high as Walpole, N. H., where Mr. S. I. Smith has even taken a specimen of *Laertias Philenor.*

Thus far our examples have been wholly drawn from among the butterflies, as the best known group of insects; but our knowledge of the Orthoptera is sufficiently advanced to show that the facts of their distribution do not militate against the conclusions drawn from the study of the butterflies. Among the Orthoptera of the Alleghanian fauna, *Gryllotalpa borealis, Œcanthus niveus, Phylloptera oblongifolia, Thyreonotus dorsalis, Chrysochraon viridis,* and *Diapheromera femorata* appear to reach only the southern limits of our blue belt; while *Tragocephala sordida, Œdipoda carolina, Hippiscus phœnicopterus, H. rugosa,* the different Tettigideans (perhaps with the exception of *Batrachidea cristata)* and *Labia minuta* probably extend to its northern boundaries. On the other hand, among the insects of the Canadian fauna, *Chloealtis conspersa, Arcyptera lineata, A. gracilis, Trimerotropis verruculata,* and *Cammula pellucida* find their southern limit at or near the southern extremity of the blue belt; the latter species also occurs on high ground farther south.

Pezotettix borealis and *P. manca* do not extend below the uppermost boundaries of the blue belt; while, among Alleghanian species, *Trimerotropis æqualis*, *Arphia xanthoptera*, and *A. sulphurea* are limited on the north by the red band, the first perhaps extending somewhat farther.

But the principal interest attaching to the distribution of insects in New Hampshire is through their relation to the White Mountains. These mountains are situated next the southern boundary of the Canadian fauna, and their valleys, as well as the lower wooded portions of their slopes, are peopled with representatives of this region; but their peaks rise from above the limit of forest growth, and maintain a fauna and flora very distinct from those below.

It has long been known that in ascending lofty mountains within the warm or temperate regions, one passes successively over areas exhibiting in their vegetation distinct features, with an ever increasing resemblance to more northern floras. The European Alps have furnished a field for extensive investigations; and their sides have been mapped into distinct zones, called, on an ascending scale, the mountain, the sub-alpine, and the alpine regions. These regions have been recognized and applied to similar phenomena elsewhere, and are in general use. It has also been noticed that the distribution of animals upon mountain summits corresponds with that of plants.

So far as plants are concerned, no distinctive alpine and sub-alpine regions have yet been recognized in the White Mountains. Dr. Asa Gray, it is true, in his statistics of the flora of the northern United States,* gives separate and extended lists of alpine and sub-alpine plants; but the only distinction made between the two is, that the former are found only in "our small alpine region" (in which he includes *all* the treeless summits of the White Mountains), and the latter "occur mainly in our alpine region, but are also found decidedly out of it;" so that the lists do not separate plants of distinct alpine and sub-alpine *zones*. Prof. E. Tuckerman, in a very interesting article upon the vegetation of the White Mountains,† says,—"Botanists designate the highest bald district, with

* *Amer. Journ. Arts and Sc.* [2], xxii, 231; xxiii, 62, 63.

† *The White Hills*, by T. S. King, p. 232.

the heads of ravines descending from it, as the alpine region, and have sometimes spoken of a small tract intermediate between the two, but still imperfectly characterized, as the sub-alpine region;" and this is the most definite mention of a sub-alpine as distinct from an alpine zone yet made by botanists.

More than ten years ago, however, I pointed out* that two distinct zones of life existed above the limits of forest growth in the White Mountains, each of which was characterized by the presence of distinct animals. So little has been added to these observations, that I have incorporated them into the present essay.

One feature of the White Mountain vegetation strikes the most casual observer, viz., the abrupt limit of the forest growth upon these mountain slopes, marking a very natural division into a wooded and a woodless district. An observant eye will detect in the latter a further subdivision into two regions,—a lower, where the dwarfed spruce, struggling upward, conceals the gray rocks by a covering of uniform green, broken only by the land-slips which have scarred the declivities with their lengthened furrows, or, by the steeper faces of precipices, where trees obtain no foothold; and an upper, much more restricted area, where the huge blocks of lichen-covered stone lie piled in inextricable confusion, one upon another, or have their interstices filled with sedges, which, on the more level spots, occasionally form small fields like pasture-land, but full of pitfalls and irregularities.

These three zones (the forest district, the district of the dwarfed spruce, and the rocky district) exhibit in a general way the limits of the mountain, the sub-alpine, and the alpine regions; and also correspond, in the characteristics of their inhabitants, to the Canadian, the Hudsonian, and the sub-arctic or Labradorian faunas. They do not, however, correspond to the divisions indicated by Tuckerman, for the "heads of ravines" and all the surrounding districts belong to the sub-alpine region, while the alpine is confined to the topmost areas of only the very highest peaks.

The separation of the mountain from the sub-alpine region is well marked by the limit of the forest growth, and this is so abrupt that a narrow belt of a few rods is usually all that intervenes between the spruce

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* *Bost. Journ. Nat. Hist.*, vii, 612–621 (1863).

of one, two, or three feet high and trees available for the market. The limit of the trees is not wholly dependent upon the elevation of the slope, but is partly influenced by the ravines, and, to a much greater extent, by the exposure of the mountain side, which causes a variation of from one to two hundred feet in altitude. Upon Mt. Madison and the north-western slope of Mt. Washington, the forest line, according to the measurements of Prof. Guyot, reaches the height of 4150 feet above the sea, and, upon the face of Mt. Clinton, which has a westerly exposure, it attains an elevation of 4250 feet; while, again, at the ledge (the most northerly extremity of the sub-alpine region on Mt. Washington), its limit is reached at about 3900 feet. The alpine region occupies the summits of only the three highest mountains, being limited to from one to two hundred feet of the cones of Mts. Adams and Jefferson, and some seven or eight hundred feet of Mt. Washington.

On Plate C I have attempted to show by the red color the general area of the alpine, and by the blue the limits of the sub-alpine region. Standing upon the summit of Mt. Washington, the main peak, and looking at the mountains which lie to the north, it will be seen that, while the sub-alpine region follows the main chain, it extends, also, a short distance along the ridge running eastwardly from the peak of Mt. Madison, and to a much greater distance north-eastwardly from Mt. Washington, in the general direction of the carriage-road, terminating, at a lower level than usual, at the ledge, around which the road abruptly turns just before it enters the forest. South of Mt. Washington there are two ridges: the more prominent and longer range, whose peaks bear the names of American statesmen, trends toward the south-west; the other continues in the direction of the main chain lying to the north of Mt. Washington, and its northernmost peaks have received the names of Davis's and Boott's spurs. A slight abutment to Mt. Washington divides the angle between these two, but is nearer the latter. By the union of these ridges, at their junction with Mt. Washington, there is formed a broad plateau, called Bigelow's lawn, sloping gradually away to the south, where the sub-alpine region finds its widest boundaries, and whose southern limits I have not traced as carefully as upon the opposite side of Mt. Washington, but which must have, approximately, the extent shown upon the map. Within this sub-alpine region, which includes also the heads of all the deeper ravines,

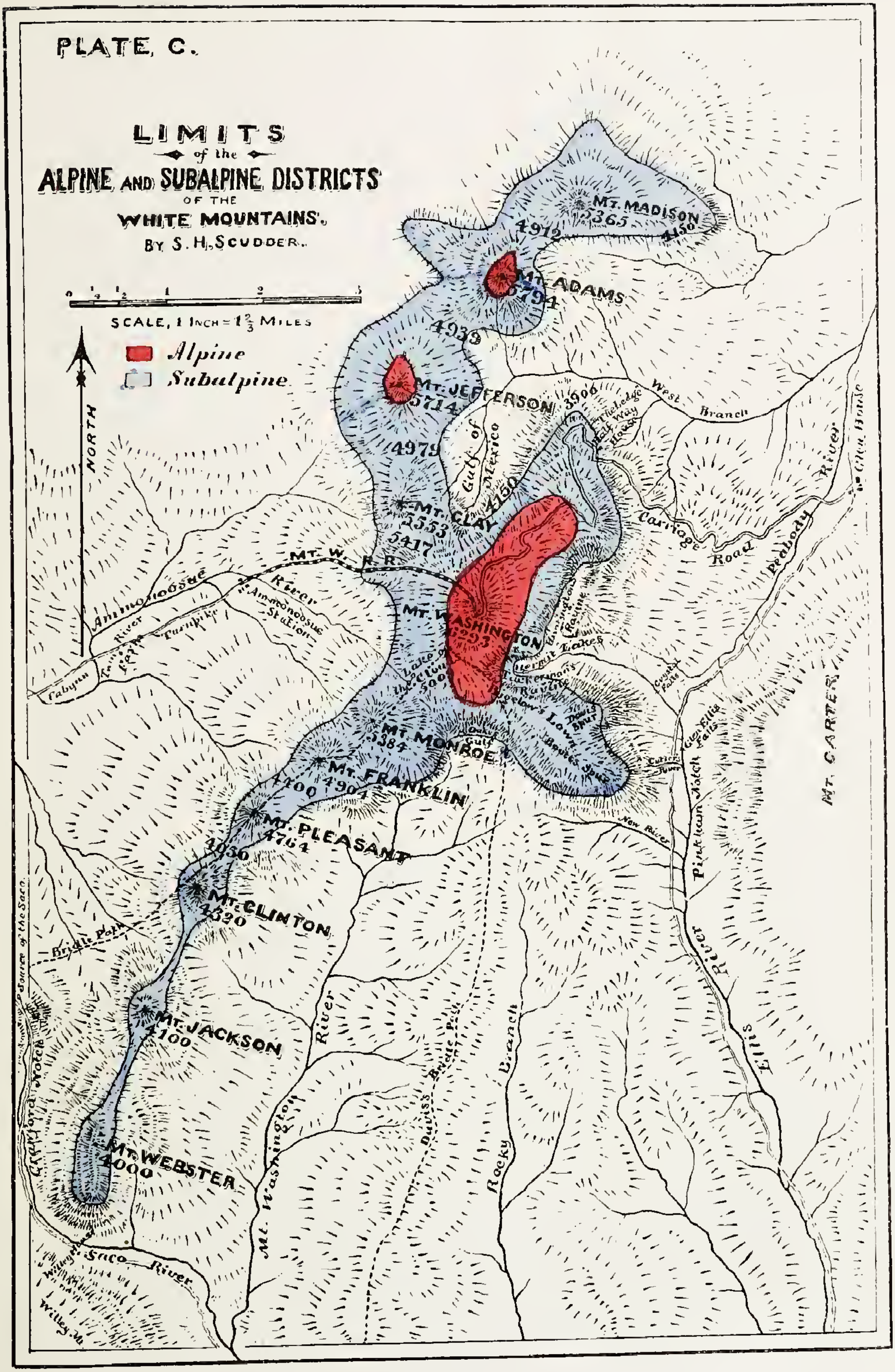
PLATE C.
LIMITS
of the
ALPINE AND SUBALPINE DISTRICTS
OF THE
WHITE MOUNTAINS.
BY S. H. SCUDDER.
SCALE, 1 INCH = $1\frac{2}{3}$ MILES
Alpine
Subalpine
NORTH
MT. MADISON
5365
4912
MT. ADAMS
5794
4939
MT. JEFFERSON
5714
4979
MT. CLAY
5553
5417
MT. WASHINGTON
6293
MT. MONROE
5384
MT. FRANKLIN
4904
4400
MT. PLEASANT
4764
4036
MT. CLINTON
4320
MT. JACKSON
4100
MT. WEBSTER
4000
Gulf of Mexico
Carriage Road
West Branch
Peabody River
Glen House
MT. W. R. R.
Ammonoosuc River
Turnpike
Fabyan
Saco River
Bridle Path
Mt. Washington River
Rocky Branch
Ellis River
Pinkham Notch
MT. CARTER
New River
Tuckerman's Ravine
Hermit Lake
Oakes Gulf
Crawford Notch
Willey H.

there are several ponds or tarns of small extent,—one in the deep gap between Adams and Madison, at the head of King's ravine, at the height of 4912 feet; several small ones upon the slopes of Adams and Jefferson; two deeper ones, known as the Lakes of the Clouds, the highest sources of the Ammonoosuc, lying at the base of Mt. Monroe on the Mt. Washington side; and other small ones on the south side of Mt. Monroe.

The alpine zone of Adams and Jefferson merely encircles their summits; that of Mt. Washington stretches north-eastwardly along the ridge which extends in that direction, occupying one or two successively lower plateaus; it also expands upon the opposite side of the mountain, over the upper portions of the widely extended plateau known as Bigelow's lawn, but it scarcely attains the Lakes of the Clouds upon the one side, or the edge of Tuckerman's ravine upon the other.

Within the limits of the sub-alpine region, and generally preferring its lower to its upper levels, we find a butterfly *(Brenthis Montinus)* and a grasshopper *(Pezotettix glacialis)*, which, so far as yet known, are wholly or almost wholly peculiar to this region. The butterfly has been taken in scanty numbers but at various localities, such as the summit of Mt. Madison, the plateaus just above the ledge, the gaps between Clay, Jefferson, and Adams, the head of Tuckerman's ravine, the adjoining portions of Bigelow's lawn, and the further extremity of the sub-alpine belt upon the summits of Mts. Clinton and Pleasant; it has also been "seen" on the top of Black mountain in Thornton, but some other species of Brenthis might easily have been mistaken for this; yet it will probably be found upon the summits of moderately high and barren mountains in the neighborhood of the White Hills. The grasshopper is abundant upon all the woodless parts of Mt. Madison, especially near the forest line; also, at and above the ledge, near the snow-bank in Tuckerman's ravine, and on the warm hillsides above the latter. It has also been taken on barren hill-tops near Norway, Me., and will doubtless be found in any similar situation in the vicinity of the White Mountain range, especially to the north.

The butterfly belongs to a genus which consists of several groups, some of which are found in the northern temperate regions of Europe and America, extending also into the colder regions. Others inhabit subarctic regions and high altitudes; while one group extends from the

sub-arctic into the arctic zone, and contains one representative, which is the most northern butterfly known, *B. polaris.** Our White Mountain butterfly belongs to the second category, having its representatives on this continent in the Hudsonian fauna. It is very closely allied to two Hudsonian species *(B. Boisduvalii* and *B. Chariclea),* and at first sight might be taken for them, especially for the former; but repeated examinations of many individuals have confirmed my first impression that they were distinct. The genus Pezotettix, to which the grasshopper belongs, is not so strictly northern as Brenthis, but has several representatives at least in the Hudsonian fauna, and, like Brenthis, is also found in the alpine elevations of Europe.

But even the narrow limit of the alpine zone of the White Mountains claims for its own a single butterfly, which probably has a more restricted range than any other in the world. One may search the season through over the comparatively vast and almost equally barren elevations within the sub-alpine district of the White Mountains, and fail to discover more than here and there a solitary individual whirled by fierce blasts down the mountain slopes, while, a few hundred feet above, the butterflies swarm in great numbers. Every passage of the sun from behind a cloud brings them out in scores, and they may often be captured as fast as they can be properly secured. The contrast between the occasional and unwilling visitor in the sub-alpine region, and the swarms which flutter about the upper plateaus, is most significant. Yet the Carices, the food-plant of the caterpillar, are quite as abundant in the lower regions as in the upper, even to the species *C. rigida,* upon which I found the larva feeding. Now this butterfly, *Œneis semidea,* belongs to a genus which is peculiar to alpine and arctic regions; in fact, it is the only genus of butterflies which is exclusively confined to them. It has numerous members, both in this country and in the old world. One is confined to the Alps of Europe; most of the European species, however, are found only in the extreme north. The genus extends across the whole continent of America, and several of its species occur on the highest elevations of the Rocky Mountains. Several species are common to Europe and America; and it is to one of these that *Œ. semidea* is most closely allied. A few species descend into the Hudsonian fauna; but, as a whole, the genus has its

* This was taken by the Polaris expedition at Polaris bay, their extreme northern station, lat. 82° 16′ N.

metropolis farther north. So that in ascending Mt. Washington, we pass, as it were, from New Hampshire to northern Labrador; on leaving the forests, we come first upon animals recalling those of the northern shores of the Gulf of St. Lawrence and the coast of Labrador opposite Newfoundland; and when we have attained the summit, we find insects which represent the fauna of Atlantic Labrador and the southern extremity of Greenland.*

We have hitherto spoken only of the barren elevations; below these we find the mountain or wooded region corresponding altogether with the Canadian fauna. The boundary line between this and the Alleghanian fauna crosses the country at about this latitude, and therefore this region forms a promontory of the Canadian fauna stretching southwardly into the Alleghanian fauna, just as occurs to a greater extent along the chain of the Green Mountains, while the Alleghanian fauna, in its turn, extends northward into the Canadian fauna, along the warmer banks of those rivers which find a southern outlet. We need only wander eight miles north of Mt. Washington itself to find, in the valley of the Androscoggin, the entomological fauna of the central portions of the New England states, while between the two, in the mountain region and in that portion of the Canadian fauna lying in the valley of the Peabody, we have such phenomena as the replacement of *Polygonia comma* of the Alleghanian fauna by *P. Faunus* of the Canadian, and of *Argynnis Aphrodite* by *A. Atlantis.*

We have, then, three distinct faunas upon the slopes of the White Mountains,† each with its characteristic forms. However much we may expect some difference between the animals of the barren summits and those of the sheltered valleys, we are struck at finding such distinct regions, each sheltering its own peculiar forms, which live, as it were, within a stone's throw of each other, and would seem to be capable of

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* Dr. A. S. Packard, writing of the region about Hopedale, Labrador, says that he found the species of Œneis in great abundance on the outer barren exposed islands, while those of Brenthis were confined to the valleys of the main land or the southerly slopes of the more protected islands, near the low stunted spruces and the more luxuriant vegetation of that desolate coast.

† It must not be supposed that all the insects which *characterize* the faunas of the barren regions have been mentioned. I have only chosen a few from many which might be given. Nearly every year fresh instances are recorded and partial lists have been made. It is unfortunate, however, that we seldom find any specification of the exact locality or height at which an insect has been taken, or of its comparative abundance; so that the notes at hand are worthless for any purposes of distinction between an alpine and a sub-alpine fauna; they serve only to show how strikingly the *general* fauna agrees with that of the *whole* of Labrador.

interchanging their stations, and yet which never pass their imperceptible barriers. Many butterflies from the valley occasionally struggle to the extremest summits, and one or two, such as *Polygonia Faunus* and *Aglais Milberti*, are frequently found within the sub-alpine region. In all, the capabilities of flight are unlimited, yet I have but two or three times taken *Œneis semidea* more than a mile and a quarter from the summit; and the appearance of the valley butterflies upon the heights may easily be accounted for, from the fact that all insects with reasonable powers of flight seem to delight in seeking the most elevated situations. Their scanty numbers in these parts is in marked contrast with their often astonishing profusion in their proper haunts below.

The results we have reached, by our study of the faunas of these mountain slopes, are what might be expected from a comparison of the elevation of these mountains with that of the European Alps, at the same time taking into consideration the difference in climate between the two countries. In the Alps the lower limit of the sub-alpine zone is placed by different writers at from 4000 to 4500 feet above the sea, and that of the alpine zone at from 6000 to 6500 feet. Now, although Mt. Blanc lies in a latitude (45° 45′) north of Mt. Washington (44° 15′) by a degree and a half, yet a comparison of the isothermal and isochimenal lines, which pass respectively through these two points, would show that a mountain elevation in Europe, which should have climatic conditions similar to those of the White Mountains, ought to be placed north of the Alps, and would be found between the mountains of Switzerland and Norway at just such a proportionate distance from them as the heights of the alpine and sub-alpine zones of the White Mountains were found to be related respectively to those of the Alps and Scandinavian mountains. By the same comparison we may also judge, that if the summit of Mt. Washington were somewhat less than two thousand feet higher, it would reach the upper limits of the alpine district, or the region of perpetual snow.

An attempt to institute a rigid comparison between the alpine and sub-alpine regions of our White Mountains and those of the Alps is not so easy as would be imagined. If we examine their physical features alone, we shall discover important differences. In New Hampshire these regions are confined solely to the summits of the very highest moun-

tains, all comprised within a few square miles, exposed almost continuously to the very fiercest gales; they are covered by interminable broken rock-masses, concealed in part by a scanty layer of mould, supporting either sedges, or stunted juniper-like spruces, whose gnarled and spreading branches creep along the ground. In Switzerland and the Tyrol these regions extend over an area of thousands of square miles, more or less continuous; the highest mountains rise above them into the region of perpetual snow, and form barriers to the wind, rendering the alpine slopes scarcely more breezy than the plains. About the Belalp, above Brieg, where I have paid most attention to the insects of the high Alps, the trees seem to reach a general level of about 6000 feet;* above them the ground is sward, richly beautified by flowers, and a pasturing ground for goats and cattle; on the slopes most exposed to the morning and midday sun, immense patches of low, dark green shrubbery, seldom rising more than a foot above the ground, dispute the soil with the grass. These patches consist mainly of heather (Calluna) with Rhododendron and several species of Vaccinium, and seem to represent the dwarfed spruces of our alpine heights, which, near the forests, are also accompanied by Vaccinium. The sward extends up to the snow and cliffs, and while sedges are no doubt present, its mass is composed of Gramineæ. During the few days early in July spent in this region, I noticed that insects, especially butterflies, were most numerous between 5500 and 8000 feet above the sea. The most abundant species of the very highest region were *Pieris Callidice* and *Erebia Manto;* and many caterpillars of *Melitæa Cynthia* were found, crawling about the rocks. Between 6500 and 7500 feet, the more common species were *Syrichtus malvæ, Œneis Aello* (not rare), *Brenthis Pales* (common), two or three species of Erebia, including *E. Manto, Colias Palæno* (common), and *Pieris Callidice* (common); *Vanessa Atalanta* and *Aglais urticæ* were also seen, the latter frequently; the species of Œneis and Brenthis seemed to occupy an identical zone. Lower down, the Blues appeared in abundance, with different species of Erebia; *Parnassius Apollo* occurred in considerable numbers, *Syrichtus malvæ* was extremely abundant, *Aglais urticæ* was very common, and eggs and young caterpillars could be found anywhere;

* Though the mountain slopes are often covered with large tracts of pasture land far below this,—a phenomenon unknown in the White Mountains.

even *Œneis Aello* was not infrequent, but *Pieris Callidice* was not seen.

Œneis Aello was very wary, and possessed of a very vigorous, energetic flight; *Œ. semidea*, on the other hand, has a very weak flight, and suffers itself to be blown about at random by the wind. This difference seems all the more striking when we remember that *Œ. semidea* inhabits a region of tempestuous winds, where existence would seem impossible to a butterfly, unless unusually gifted. Both species, when at rest, sit with wings back to back, the front pair concealed as much as possible between the hind pair; but *Œ. Aello* always sits erect, or only slightly inclined, while *Œ. semidea* is rarely erect, and often, when it has alighted upon the horizontal surface of a rock or by the muddy brim of a pool, fairly lies upon its side, as if dead.

In the following pages we give a list of the butterflies and Orthoptera of New Hampshire, as far as they are known. The list of Orthoptera is given almost entirely from memoranda collected by myself. For notes on the butterflies, I am indebted to many persons, but especially to Mr. C. P. Whitney, of Milford, N. H. In this list I have incorporated as full an account as possible of the two butterflies peculiar to the barren summits of the White Mountains.

II. List of the Butterflies of New Hampshire, with Notes on their Geographical Distribution.

The names used in the accompanying list are those of my Systematic Revision of some of the American Butterflies.

NYMPHALES.

1. *Œneis semidea* Butl.

[Plate A, Figs. 2, 4, 6, 9, 11, 13, 14; 2, imago; 4, chrysalis, dorsal view; 6, ib., side view; 9, larva, dorsal view of hinder extremity; 11, ib., head; 13, ib., side view; 14, ib., dorsal view.]

As stated in the first part of this memoir, this insect probably occupies a more restricted geographical area than any other butterfly in the world, the narrow area of the alpine fauna of the White Mountains. Dr. Harris's assertion that "it has also been seen on the Monadnock mountain, and will probably be discovered on the tops of the high mountains in our

own state" (Massachusetts), is wholly erroneous. I have ascended Greylock, the highest mountain in Massachusetts, more than twenty times, and at all seasons of the year, and certainly could not have failed to see this butterfly did it occur there. Since Monadnock is a naked peak, it would certainly be a more propable habitat for the insect; but the limitation of its distribution in the White Mountains wholly forbids the possibility of its presence on a much lower and isolated mountain to the south.

The butterfly is found most abundantly from about one quarter to three quarters of a mile from the summit of Mt. Washington, or at an elevation of from 5600 to 6200 feet above the sea. It often alights on the flowers of *Silene acaulis* Linn., and also upon some of the Ericaceæ, particularly on a species of Vaccinium; but the best collecting places are the sedgy plateaus of the north-eastern and southern sides of the mountain, where the collector will also obtain a good footing, a matter of no small importance on such a collecting ground. I have never found the butterfly at the head of any of the deep ravines.

Dr. Meyer-Dür states of *Œ. Aello*, the species occurring in the European Alps, that it inhabits the calcareous and central mountains,—not the highest chains, as has been generally supposed, but rather the middle regions, from 4000 to 6000 feet above the sea.* He also makes the remarkable assertion that the butterfly appears, at least in Switzerland,† only on *alternate* years, namely, those with even numbers. Prof. Frey thinks this to be true only for each special locality, but that every year it may be found in some of them.

All the species of this family of butterflies, so far as they are known, feed in the caterpillar state on grasses; ‡ but as the true grasses are rare in the inhospitable region where this insect is found, being replaced almost altogether by sedges, the caterpillar feeds upon the latter. Mr. Sanborn has seen them eating it by day, and, by the aid of a lantern, I discovered

* See our previous remarks on this species, p. 343.

† Meyer-Dür says further, that the records of its capture out of Switzerland are also in even years; but, since writing the above, I notice that Speyer, in his work on the geographical distribution of the Lepidoptera of Germany and Switzerland (II, 271), says that, according to Trapp, it appears every year, but in some years more abundantly than in others.

‡ This is not strictly true, as I thought when writing it. Boisduval, Rambur, and Graslin, in their work on the caterpillars of Europe, state that *Cœnonympha Corinna* feeds both on Triticum and Carex; and Wilde, according to Kaltenbach (Pflanzenfeinde, 728), gives Lolium and Carex as the food of *Pararge Achine*.

them feeding on the same plant, *Carex rigida*, by night. This shows that I was mistaken in a belief formerly expressed, that they fed upon lichens.

Œneis semidea was first discovered about half a century ago, and described by Say from specimens sent him by Dr. Pickering and Prof. Nuttall, of Boston. Very few specimens seem to have been taken since that time, until 1859, when I made my first considerable collections in the White Mountains. I ascended the highest peak on July 8, for the express purpose of finding the butterfly, and secured my first specimen at about a mile from the summit, near the foot-path from the Glen. On ascending, the butterfly became more abundant; and, although our party hastened over the ground, more than forty good specimens were taken, and a friend even captured seven without a net. Less than a week afterwards, in a little more than an hour's collecting, fifty-nine were taken, for, in its season, this butterfly is exceedingly abundant.

Dr. Harris gives "June and July" as the season of the flight of the imago, the former date on the authority of Oakes, who found the insect abundant in June, 1826. Undoubtedly this was toward the close of the month. It usually begins to appear very early (the first week) in July, becomes exceedingly abundant before the middle of the month, and continues until about the second week in August. Mr. Sanborn gives July 4th as its earliest appearance in 1869, and only one more specimen was seen before the 9th, although the weather was favorable. This may serve, I think, as an average date, and the butterflies will best be taken in the second and third weeks in July. They lay their eggs until about the 22d of July, and probably a little later. These are apparently dropped loosely among the sedges, for I could obtain no eggs on the sedge itself from gravid females confined in open kegs, and finally, searching among the roots as a last resort, I discovered a single egg, which, however, never hatched. Caterpillars have been found by Mr. Sanborn, the late Mr. Shurtleff, and myself, nearly full grown, on the 2d of August, and others certainly full grown on August 19. More recently Mr. Whitney has found them "apparently fully grown, under stones." They were unquestionably seeking a good place to undergo their transformations. They probably transform to chrysalids at once, and hibernate in that state, although it is possible that they winter as Mr. Whitney found them. In

the early part of July, 1869, Mr. Sanborn searched very carefully for the chrysalids of this species, spending ten or twelve hours in raising movable surface stones, and in four or five places clearing away to the depth of several feet the smaller blocks of stone lying in the "rock rivulets," as he appropriately terms the slight gulleys wholly devoid of vegetation, which are scattered everywhere over the plateaus, and which mark the course of the surface waters after rain. He succeeded in securing only two living specimens. Nine others were either infested by ichneumons (*Eulophus semideæ* Pack., and *Encyrtus Montinus* Pack., described below*), or were the empty shells of the previous year. They were all found imbedded between the sides of the rock and the long, dense, crisp moss surrounding it, between half an inch and an inch and a half below

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* "*Eulophus semideæ* nov. sp. [Fig. 46]. Belongs apparently to the same section of the genus as *E. amempsimus* Walk.

"♂ (two specimens). Antennæ filiform, not increasing in width toward the tip, rather long, much longer than in *E. amempsimus*, and very hairy, dark brown. Head deep blue, shining, punctured as usual, under a not powerful lens; mandibles, and other mouth parts, pale piceous; thorax, as well as the whole body, deep blue; fore wings broader at end, clear; spur distinct, dilated at tip; coxæ concolorous with body; trochanters and femora brown, tips of latter pale testaceous; tibiæ brown, pale at tip, or almost wholly pale; tarsi dark on terminal joint, the last joints of hinder pair dark; abdomen as long as the thorax, narrow lanceolate oval, subacutely pointed, more so than in *E. amempsimus*, concolorous with rest of body, but with steel blue reflections at base. Length, .06 inch."

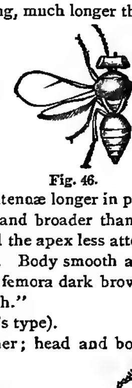


Fig. 46.

"♀ (ten specimens). Eyes rather larger, and a little nearer together than in the ♂; antennæ longer in proportion than in *E. amempsimus*, the club being much longer. The whole body is shorter and broader than in *E. amempsimus* and *E. eneugamus* Walk., the abdomen especially being much broader, and the apex less attenuate; of the same color as the ♂, with the base of the abdomen more distinctly steel blue. Body smooth and shining, not perceptibly punctate under a strong lens. Legs: trochanters whitish at tip; femora dark brown, whitish at each end; tibiæ and tarsi white, the terminal joint of tarsi dusky. Length .08 inch."

"*Encyrtus Montinus* nov. sp. [Fig. 47]. Closely allied to *E. Swederi* of Europe (Walker's type).

"♀ (one specimen). Ocelli placed in a narrow triangle; eyes large and near together; head and body beneath testaceous; a row of minute pits along the orbits in front, rather remote from the eyes; mouth parts concolorous with the head; antennæ: joint two flattened, clavate; joints one to three darker than the head, four to seven brown, eight and nine yellowish, ten and eleven (club) blackish; the eight terminal joints hairy; prothorax concolorous with the head; the rest of the thorax and the propodeum bluish green (not very dark) with metallic reflections; surface smooth and shining, with small, not dense punctures; sides of thorax below the insertion of wings, and legs dark testaceous; tegulæ dull testaceous; wings smoky, paler toward the outer edge, with a broad, curved, conspicuous white band, extending from the pterostigma, where it is dilated, across to the inner edge of the wing; pterostigma with a slight spur toward the centre of the wing, enclosing a narrow V-shaped space; abdomen regularly triangular, the tip acute, a little longer than broad, being being pretty short, dark brown, shining, sending off dull metallic hues; under side of a paler bronze color. Length .09 inch."

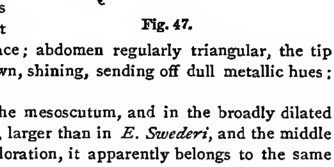


Fig. 47.

"Differs from *E. Swederi* in not having any twin tuft of hairs on the mesoscutum, and in the broadly dilated second antennal joint; the middle pair of legs has a large tibial spur, larger than in *E. Swederi*, and the middle tarsi are larger; otherwise, except in the remarkable differences in coloration, it apparently belongs to the same section of the genus as *E. Swederi*."

"'Found alive in an old chrysalis case of *Œ. semidea*,' Mt. Washington. F. G. Sanborn."—*Communication of Dr. A. S. Packard.*

the general surface, where the caterpillars had entered. They were not attached to the rock or the moss, but lay in horizontal oval cells, evidently formed by the movements of the caterpillar before pupation. The most particular examination revealed no trace of any web or silken thread, even as a lining of the cell. Mr. Sanborn's impressions, drawn mainly from a comparison between the slender number of specimens he obtained and the abundance of the butterfly, are, that the healthier caterpillars penetrate even deeper into the ground; but as I have also found them under or beside surface stones, and Mr. Whitney has discovered larvæ ready for their change in similar localities, I am more disposed to believe that the place to seek them is beneath and beside the uppermost stones, and especially at the edges of the "rock rivulets," where the vegetation is usually the freshest. To one familiar with the locality,—a surface almost completely strewn with angular rock fragments,—Mr. Sanborn's exploration will seem to have been a very successful one. Most of his specimens were found at more than a mile from the summit; doubtless better success would attend efforts in localities not more than half or three quarters of a mile from the top.

One would suppose that insects, whose home is almost always swept by the fiercest blasts, would be provided with powerful wings fitting them for strong and sustained flight; but the contrary is true. They can offer no resistance to the winds, and whenever they ascend more than their accustomed two or three feet above the surface of the ground, or pass the shelter of some projecting ledge of rocks, they are whirled headlong to immense distances, until they can again hug the earth. Their flight is sluggish and heavy, and has less of the dancing movement than one is accustomed to see in the Oreades.* They are easily captured.

The European Aello appears, says Meyer-Dür, among the earliest butterflies of the Alps. It is seen soon after the snow melts,—first, on the lower grounds at the end of May; last, on the higher levels (corresponding more nearly to those to which our species is restricted) at about the beginning of July; it disappears in the same way from the end of June to the end of the first week in August.

2. *Enodia Portlandia* Scudd. Within the limits of New England this is a very rare insect. It may be found occasionally upon the banks of

* See p. 346.

the southern Connecticut, since Mr. Emery reports that it is "not uncommon" in certain stations about Holyoke and Mt. Tom in Massachusetts. I have also taken two battered specimens at Jefferson, in the White Mountains. Gosse took it at Compton, Lower Canada, and D'Urban on the River Rouge, north of the Ottawa; three or four specimens have also been captured at Suncook, N. H. (Thaxter).

3. *Minois Alope* Scudd. This insect is tolerably abundant, sometimes very common, in the southern half of New England, occurring throughout Massachusetts and the two states lying south of it, and in the southern extremities of Maine, New Hampshire, and Vermont. The most northern localities from which I have seen specimens, or received notes of its capture, are Norway, Me. (Smith), Thornton and Shelburne, N. H. (Faxon), and Sudbury, Vt. Mr. Jones states that it is also found in Nova Scotia. It occurs in open woods and orchards, as well as along roadsides and stone walls, especially such as are overgrown with brambles or skirted by shrubbery.

4. *Minois Nephele* Scudd. This insect is found over the whole northern half of New England in great abundance. The only locality in which I have met with it in Massachusetts is the elevated region about Williamstown, but it undoubtedly approaches closely to the northern limits of the state.

5. *Argus Eurydice* Scudd. In New England this is not a very rare insect, especially in the northern and elevated parts. There is no notice of its capture south of Massachusetts, nor in the Connecticut valley south of New Hampshire. In the latitude of the White Mountains, and as far south as Campton, it will be found extremely abundant by those who look for it in its proper haunts, elevated moist meadows.

6. *Megisto Eurytus* Scudd. The northern limit of this butterfly probably follows the isotherm of 45°, for this seems to be its boundary in New England, since it is found in some abundance in Walpole (Smith) and Milford, N. H. (Whitney). There is no record of it farther north, excepting at Norway, Me., where Mr. Smith found it in abundance; at Plymouth, where it is not very common (Scudder); and at Brunswick, Me. (Packard), toward which place, being on the sea-coast, the isotherm probably turns. It does not occur among the White Mountains, but probably will be found close to their southern boundaries, and quite as far north in Vermont.

7. *Danaus Plexippus* Latr. This butterfly ranges over the whole North American continent from Atlantic to Pacific (excluding perhaps the Rocky Mountain district), as far north as the annual isotherm of 40°, and over that portion of South America lying east of the Andes and north of Rio de Janeiro, including, also, many and perhaps all of the West India islands. It occurs throughout New England, but it is much more rare in the northern than in the southern part, though even here it can hardly be called abundant, for, usually, specimens must be captured singly. Yet, now and again, it swarms, as in the autumn of 1871. In some localities it is especially numerous,—such places, for instance, as islands off the coast, or broad sandy sea-beaches, where no Asclepias grows. Is it that an innate propensity for geographical extension leads it to the last possible limit? Mr. L. L. Thaxter states that it is found in great numbers on Appledore, the largest of the Isles of Shoals, which has a surface of about 500 acres; yet there is no trace of milk-weed upon any of these islands, which he has thoroughly explored. It has not been recorded from the White Mountains.

8. *Basilarchia Disippe* Scudd. Within New England, Disippe occurs abundantly in the south, sparingly in the north, although found in the very heart of the White Mountains. Gosse does not record it from Compton, Canada; and the northernmost points from which specimens have been reported are Mt. Desert (Scudder), Waterville (Hamlin), and Norway, Me. (Smith), the Glen, White Mountains, and Sudbury, Vt. (Scudder).

9. *Basilarchia Astyanax* Scudd. The general range of this butterfly is similar to that of the preceding, though less extensive. It is tolerably abundant in the southern parts of New England, and occurs about as far north as the annual isotherm of 45°, the northernmost points recorded being Dublin (Faxon) and Milford, common (Whitney).

10. *Basilarchia Arthemis* Scudd. This species of Basilarchia has a very different range from the two preceding, its southern limits nearly coinciding with the northern boundaries of *B. astyanax.* In New England it has not been taken south of Massachusetts, and but rarely in that state. It is already common at Brattleborough, Vt., Walpole (Smith), Weare (Emery), and Dublin, N. H. (Faxon and Leonard); but it is said to be scarce in Milford (Whitney), and in the immediate neighborhood of

Dublin. In the White Mountain region, and in northern New England generally, it is exceedingly abundant, far more so than the other species of the genus in their most favorable localities. Indeed, the matrons of farm-houses, in the valley of Peabody river, complain of the insects entering the kitchens in such numbers as to be a very nuisance. One of them, Mrs. Dolly Copp, of "Imp cottage" (well known to many frequenters of "the Glen"), relates how she has taken more than fifty on the inside of her windows in a single morning.

11. *Polygonia interrogationis* Scudd. In New England this butterfly is nowhere very abundant, and in the northern portions very rare. The northernmost localities from which it is reported are Brunswick (Packard) and Norway, Me. (Smith), and Walpole (Smith) and Milford, N. H., one specimen only (Whitney).

12. *Polygonia comma* Scudd. is found throughout New England, excepting in the White Mountain region, and perhaps other elevated portions of the northern counties. It has, however, been taken on Camel's Hump, Vt. (Sprague), and given as a probable inhabitant of Norway, Me. (Smith).

13. *Polygonia Faunus* Scudd. This butterfly is as peculiar to the Canadian fauna as *P. comma* is to the Alleghanian. In New England it is found only in the north, the southernmost localities from which it has been recorded being Williamstown, Mass. (Scudder), Dover and Camel's Hump, Vt. (Sprague), Dublin (Faxon) and Milford, N. H., two specimens (Whitney), and Norway, Me. (Smith). In the valleys of the White Mountains it is exceedingly abundant, and is the butterfly oftenest seen in deep ravines and on mountain slopes below the sub-alpine region. More than any other species belonging to the mountain region, it mounts to the very summit of the highest peaks, far above any plant upon which its larva would be likely to feed. Edwards reports a single specimen from West Virginia, and Abbott records it from the mountains of Georgia! I consider *P. gracilis* a dimorphic form of this species.

14. *Polygonia Progne* Hübn. [Plate A., Fig. 12.] The range of this butterfly corresponds very closely with that of *P. comma.* In New England it is more generally distributed and universally common than any other species of Polygonia. It is somewhat more abundant in the southern than in the northern parts. I have this spring taken a single specimen in the White Mountain region. It is common in some seasons at

Norway, Me. (Smith), and has been found at Thornton and Shelburne, N. H. (Faxon). It will probably prove to be rare in the elevated regions of northern New Hampshire and Maine.

15. *Nymphalis J. album* Scudd. occurs throughout New England, although very rare in the northernmost portions. In the White Mountain district and its vicinity it is abundant, as it doubtless is through all that portion of New England lying north of the isotherm of 40°, for the spring months. Mr. Roland Thaxter mentions it as exceedingly common at Suncook, but it is much less so at Milford (Whitney).

16. *Papilio Antiopa* Linn. This butterfly is apparently distributed over the entire breadth of the Northern Hemisphere below the arctic circle, as far as the thirtieth parallel of latitude in America, and the fortieth in the old world. It is found in nearly equal abundance through all parts of New England, so numerous, indeed, as to become positively injurious on account of the damage done by the caterpillar to some of our choicest ornamental trees.

17. *Aglais Milberti* Scudd. This insect is found throughout New England, but is extremely rare in the southern portions. Probably the isotherm of 23° for the winter months would mark the limit of its abundance. It is rather common in Walpole, Dublin, Milford, and the Isles of Shoals. Still farther north it is very abundant, often the commonest species in its season, and is plentiful even in the White Mountain region itself.

18. *Vanessa Atalanta* Fabr. This butterfly enjoys a very extensive geographical range, extending over nearly the whole of the North American and European continents. I believe it is found plentifully, and in nearly equal numbers, through every part of New England, although there is no record of its capture in the heart of the White Mountain region. As the abundance of this species is more than ordinarily affected by the action of parasites, the records of a single year for any locality are comparatively valueless.

19. *Vanessa Huntera* Hübn. It is far more common in the southern than in the northern portions of New England, and is wholly wanting in the White Mountain district, although occurring as far north as Quebec. The northernmost localities from which it has been reported are Waterville, very few (Hamlin), and Norway, Me. (Smith), and Milford, N. H., scarce (Whitney).

20. *Vanessa cardui* Ochs. This insect, says Speyer,* "is the most widely distributed of all butterflies, and perhaps of all Lepidoptera. It inhabits the whole of Europe as far north as Lapland, the whole of Asia (with perhaps the exception of the polar regions), the whole of Africa, America from Hudson's bay to Brazil, and Australia; that is to say, all parts of the world, every zone, the northern as well as the southern hemisphere, its area of dispersion embracing little less than the whole globe. Moreover, in the warm regions it is by no means restricted to the higher altitudes, but inhabits the plains under the equator as well as in Lapland. It has therefore nowhere on the earth an inferior limit to its distribution, through excess of temperature or insufficiency of moisture. As to its upper limits, it is restricted only by the eternal snows of the loftiest mountains. It is, however, not yet determined whether it is found in the treeless regions of the arctic zone, as it is in the sub-glacial districts of the Alps." There is no spot in New England where it may not be found at certain seasons in abundance.

21. *Junonia Cœnia* Hübn. In New England this is an exceedingly rare insect. Mr. Smith has seen several specimens from the vicinity of New Haven; Mr. McCurdy found it somewhat plentiful one autumn in the vicinity of Norwich, Conn.; Col. Higginson reports several from Newport, R. I.; and Mr. Bennett captured a single specimen at Springfield. Mr. Sanborn and myself have both taken specimens on Cape Cod. Dr. Harris took one specimen at Milton, Mass.; and I have captured a single individual at Hampton, N. H., the northernmost locality from which it has been reported in New England, or, indeed, in America.

22. *Speyeria Idalia* Scudd. Generally speaking this is not a common insect in New England, and is seldom seen above the annual isotherm of 45°. The most northerly stations from which it is recorded are Brunswick, Me. (Packard), Isles of Shoals, a few specimens, and Suncook, not common (Thaxter), Milford, common (Whitney), Dublin (Faxon), and Walpole, N. H. (Smith).

23. *Argynnis Cybele* God. In New England this insect is scarcely larger than *A. Aphrodite*, and the two species have frequently been confounded, but it is found throughout the whole area, excepting the White

* Geogr. Verbr. Schmett., 1, 182.

Mountain region, and probably most of the country farther north. In the northern half of the district it is uncommon, but in the extreme south exceedingly abundant. The most northern known localities are Brunswick, Waterville, and Norway, Me.; and in New Hampshire, Isles of Shoals (not common), Suncook (not common), Milford (very abundant), Walpole, and Plymouth.

24. *Argynnis Aphrodite* God. In New England this is one of our commonest butterflies, but it is wholly absent from the White Mountain region, where it is replaced by the next species.

25. *Argynnis Atlantis* Edw. Abundant through all the cooler parts of Canada, and very closely limited southwardly by the annual isotherm of 45°, only surpassing it in elevated regions and along mountain chains. In New England it is probably common everywhere north of the isotherm of 45° maximum temperature for the spring months, but is really abundant only in the White Mountain district, where it wholly replaces *A. Aphrodite.* Other New Hampshire localities are Thornton, Shelburne (Faxon, Minot), Littleton (Sanborn), Jefferson (Scudder), and even Suncook (Thaxter), Dublin (Faxon), and Milford, very rare (Whitney).

26. *Brenthis Myrina* Herr.-Schäff. This butterfly is found in nearly equal abundance throughout New England, in the valleys of the White Mountains, or by the sea-coast.

27. *Brenthis Montinus* Scudd. [Plate A., Fig. 1]. The geographical range of this insect has been sufficiently indicated in the first part of this paper, in the discussion of the sub-alpine zone. Very little can be added to what has already been published concerning the seasons of this insect. It has been found from July 21 to August 18. Specimens captured August 2 had well developed eggs; others taken August 11 were "in good condition." It is therefore probable, from analogy with the other species of the genus inhabiting New England, that the butterflies first appear in the middle or latter part of June, and lay their eggs about the middle of August; that these hatch at once, and that the embryonic caterpillars hibernate, reviving sufficiently in the spring to undergo their changes and appear on the wing in June. Perhaps, however, some of these caterpillars become lethargic and transform later, so as to appear on the wing in August (while the June butterflies are laying their eggs), for fresh individuals have been captured on August 11. Should observers

find females at this date with undeveloped eggs, this theory would seem more plausible, and might throw some light on the origin of the vernal series in the other species. It should be added that, in Europe, only one brood has been observed among the mountain species of this genus.

Probably no collector has seen more than eight or ten of these butterflies in a day's scramble among the mountains, but if sought early in July they might be found in greater abundance. They fly close to the ground among the scanty foliage growing in the rocky crevices of the steep mountain slopes. Messrs. Sanborn and Whitney have often seen them on the mountain willow, *Salix herbacea* Linn., which grows but a few inches above the ground. So frequent and prolonged were their visitations to this plant, that these observers sought carefully but in vain for eggs. It is more probable that the caterpillar feeds upon some of the Violaceæ.

28. *Brenthis Bellona* Herr.-Schäff. In New England this butterfly appears to be as well distributed and as common as *B. Myrina*, although elsewhere it is considered somewhat less abundant.

29. *Phyciodes Tharos* Kirb. In New England this species is almost everywhere exceedingly abundant. It is not uncommon even in the White Mountain district; but Mr. Smith, who has collected largely in Norway, Me., writes that he has never seen a dozen specimens there.

30. *Charidryas Nycteis* Scudd. In New England this is a very rare insect. Mr. Sanborn has found a single specimen in the Glen, at the base of the White Mountains, and Mr. Smith one at Walpole. The general distribution of this insect leads us to anticipate its occurrence anywhere in the southern half of New Hampshire.

31. *Limnœcia Harrisii* Scudd. Specimens of the imago have been taken among the White Mountains, and the sides of the Glen road swarm with the caterpillars at the proper season. It has also been found at Pittsfield (Treat), Dublin (Faxon), and Milford, rare and local (Whitney). It seems to be more common in the elevated and northern districts than elsewhere, and has seldom been found outside of the state.

32. *Euphydryas Phaeton* Scudd. This butterfly is so eminently local in its habits that it has not yet been found over the extent of country which it probably occupies. In New England it is found abundantly everywhere, from the heart of the White Mountains to the lower portion

of the Connecticut river valley, but, owing to its local habits, it is ordinarily esteemed rare. It occurs only in moist, or moist and shady, meadows of small extent. When young, it feeds on *Chelone glabra;* after hibernating, on *Lonicera ciliata.*

33. *Libythea Bachmanii* Kirtl. Two specimens of this butterfly have been taken at Littleton by Dr. F. F. Hodgman. With a single exception, this is the only known instance of its occurrence in New England.

RURALES.

34. *Thecla Liparops* LeC. This butterfly appears to be found throughout New England, although everywhere considered a rare species. In New Hampshire it has only been reported from Mt. Moriah, Thornton (Faxon), and Milford (Whitney).

35. *Thecla Edwardsii* Saund. Has been taken only in the extreme southern parts of the state, Milford (Whitney) and Nashua (Harris).

36. *Thecla Calanus* Doubl. This butterfly seems to occur throughout New England. In New Hampshire, it is very common at Walpole (Smith), but is probably absent from the northern and perhaps the central parts of the state, although it occurs at Norway, Me.

37. *Thecla acadica* Edw. This butterfly is rather widely distributed in New England. In New Hampshire it has been taken only at Milford, "very rare" (Whitney), and at Nashua (Harris).

38. *Callipareus Melinus* Scudd. A widely spread species that will probably be found in every part of the United States. In New England it is more abundant in the south than in the north, although it has been taken as far north as Norway, Me., and Plymouth, N. H. Other localities in New Hampshire are Dublin (Faxon), Suncook (Thaxter), and Milford (Whitney).

39. *Incisalia Augustus* Min. The distribution of this insect seems to be somewhat peculiar. Apparently reaching its maximum of development in New England, it occurs also in the Canadian fauna, even as far as the Cumberland house on the Saskatchawan, nearly in the centre of the continent, and has been described from California as a distinct species. Yet notwithstanding its occurrence in California, it has not otherwise been reported in the United States west of Albany. In New England it is widely distributed, and will probably be found in abundance all over

the wilder portion. It has not been reported from the White Mountains, and its northernmost known station is Norway, Me., very common (Smith). In Milford, N. H., it is rather uncommon (Whitney).

40. *Incisalia Niphon* Min. In New England this butterfly has been found in widely separated localities, more abundantly at the south than at the north. It has been taken in Norway, Me. (Smith), the White Mountains (Sanborn), and Milford, N. H., common (Whitney).

41. *Incisalia Irus* Scudd. The only known locality for this butterfly in New Hampshire is Milford, where it is scarce (Whitney).

42. *Strymon Titus* Butl. In New England it is considered a rare insect, but has occasionally been found in considerable numbers, and is well distributed at least over the southern portions. The only northern locality in which it has been found is Norway, Me., where it occurs in abundance (Smith). In New Hampshire it has been taken only at Milford, not common (Whitney).

43. *Cyaniris neglecta* Scudd. This butterfly is found across the continent. We may therefore naturally presume that it is found throughout New England. It is common in the southern half, but it is not often reported from the northern portions; perhaps, however, this is rather due to the lack of observers. Our northernmost recorded localities are Norway, Me. (Smith), and Dublin, N. H., "quite plenty" (Faxon).

44. *Cyaniris violacea* Scudd. This is by no means an uncommon insect in New England, but has generally been mistaken for one of the other species (coming, as it does, midway between neglecta and Lucia), on account of the absence in New England of the dark form of the female. Probably it will prove comparatively rare in the northern half. It has been taken at Walpole and Milford.

45. *Cyaniris Lucia* Scudd. This is an abundant insect throughout the northern half of New England, and cannot be called very uncommon even in Massachusetts.

46. *Everes Comyntas* Scudd. is found throughout New England, even in the White Mountain district, and is everywhere a common insect, especially in the southern half.

47. *Chrysophanus Hyllus* Hübn. In New England it has never been taken east of the Connecticut valley; and in New Hampshire only at Walpole, a single specimen (Smith).

48. *Chrysophanus epixanthe* Westw. In New England this butterfly has only been found east of the Connecticut valley. In New Hampshire it has been taken at Milford, very plentiful in a few localities (Whitney), Suncook, not common (Thaxter), and Hampton, abundant (Scudder).

49. *Lycæna americana* Harr. It is found throughout New England, almost as abundantly in the White Mountain district as elsewhere, and is one of our commonest species.

50. *Feniseca Tarquinius* Grote. The latitudinal distribution of this butterfly is greater than that of any other of the American coppers, since it is found from beyond the limits of the Alleghanian fauna on the north to the shores of the Gulf of Mexico. In New Hampshire it has been taken at Berlin Falls, Thornton, "very abundant below the cascade on Mill brook" (Faxon), Waterville, Manchester, and Milford.

PAPILIONIDÆ.

51. *Colias Philodice* God. In New England this butterfly is everywhere the commonest species, except in certain years, when it seems to be affected by some unfavorable circumstances. It is found alike in the White Mountain region and on the shores of the Sound, but is more abundant in the southern than in the northern districts.

52. *Eurema Lisa* Kirb. This butterfly is a member of the Carolinian fauna, where it is very abundant. A single specimen has been taken by Mr. Thaxter at the Isles of Shoals.

53. *Ganoris rapæ* Dalm. This butterfly is our most recent and least desirable importation from the old world, and before many years it will doubtless spread over the whole northern hemisphere. It was introduced at Quebec, and has rapidly spread southward and westward. The first specimens taken near New Hampshire were captured by Mr. Merrill, at Waterbury, Vt., in August, 1867; yet it was only in May of the same year that they appeared at Montreal. In August, 1868, they were not uncommon at Island Pond, on the Grand Trunk Railway, and the succeeding year were taken in July by Mr. Sanborn, at Littleton, and by Mr. Whorf, at Shelburne, and, in August, as far south as Campton, by the latter gentleman. It was not until September of the same year that they were discovered at Norway, Me., a few miles from Shelburne; and yet they were taken at Waterville, in the same state, in May of that year,

and still farther south, at Lewiston, even in the previous year! In 1870, the vanguard of the army crossed the state, reaching Milford in May, but they had even then penetrated as far as Springfield, in their march down the Connecticut, and were abundant at Walpole. They swarm now in every part of the state, not even excepting the Isles of Shoals, where Mr. Thaxter found them in 1870, and the alpine zone of the White Mountains, where I took fresh specimens in 1873.

54. *Ganoris oleracea* Scudd. [Plate A, Fig. 8.] It is found throughout New England, although seldom abundant south of the annual isotherm of 48°. Northward and eastward it is everywhere abundant, and continues to be so as far south as Williamstown, Mass., Dublin, N. H., and Portland, Me. It rarely occurs south of the northern boundary of Connecticut.

55. *Laertias Philenor* Hübn. [Plate A, Fig. 15, chrysalis, side view. Fig. 17, ib., dorsal view.] In New England this butterfly is very rare. In no locality has more than a single specimen been taken during a season, excepting near New Haven; one was taken and another seen by Mr. Smith, at Walpole, N. H., in 1870.

56. *Pterourus Troilus* Scudd. In New England this insect is not uncommon in the three southern states, and has been found north of Massachusetts, at Milford, not as common as Polyxenes (Whitney), Dublin (Faxon), and Walpole, N. H. (Smith), and at Sudbury, Vt., scarce (Scudder).

57. *Euphœades Glaucus* Hübn. [Plate A, Fig. 16.] This butterfly is more widely distributed than any other of our swallow-tails, for it is found in nearly every part of North America, from the Atlantic to the Pacific, from Newfoundland to northern Florida, and from central Alaska to California. Its northern limit in the eastern half of the continent closely follows the dividing line between the Canadian and Huronian faunas, as laid down by Allen. In New England it is everywhere common, from the summit of Mt. Washington to Long Island sound, but is more abundant in the northern than in the southern districts. In the White Mountain region it is exceedingly abundant, and individuals are often dusky and small, like those from Alaska.

58. *Amaryssus Polyxenes* Scudd. This insect is rather uniformly common throughout New England, although not mentioned by Gosse

among the butterflies of Compton, Lower Canada, which is rather strange, since it is found in the valleys of the White Mountains.

URBICOLÆ.

59. *Epargyreus Tityrus* Scudd. This is a tolerably common, sometimes abundant species in the three southern New England states, occurring even in the elevated portions. North of this it becomes rare, having been taken in New Hampshire only at Milford, "plenty" (Whitney), Dover (Faxon), Walpole (Smith), and Plymouth (Scudder).

60. *Achalarus Lycidas* Scudd. This is a rare insect in New England. It has occasionally occurred in abundance in New Haven and vicinity, and a few specimens are reported at rare intervals in various parts of Massachusetts. Mr. Whitney has taken three or four specimens at Milford, the northernmost known locality for this insect.

61. *Thorybes Pylades* Scudd. It is found in abundance in every part of New England.

62. *Erynnis Persius* Scudd. In New England it is everywhere common, from the valleys of the White Mountains and Norway, Me., to Cape Cod, Norwich, and New Haven.

63. *Erynnis Lucilius* Scudd. This insect has not been recorded from New Hampshire; but I have found empty nests of the larva among the leaves of Aquilegia in Plymouth, which must have been made by this species.

64. *Erynnis Icelus* Scudd. It is widely spread over New England, having been taken at nearly every place where there are resident collectors. In the north it has been found in the wilds of Maine, at Norway in the same state, in the valleys, and even in the sub-alpine zone of the White Mountains, at Plymouth, and farther south at Milford.

65. *Erynnis Brizo* Scudd. This, too, is widely spread in New England, but has not yet been found in the White Mountain valleys, although it has been taken at Waterville, Me., and Thornton, N. H. It has also been reported from Dublin and Milford, in the southern part of New Hampshire.

66. *Erynnis Juvenalis* Scudd. This butterfly is confined in New England to the three southern states, having been taken north of them in but a single locality (Milford, N. H.), where it is reported rare.

67. *Pholisora Catullus* Scudd. In New England this is not an uncommon insect in some southern localities, notably along the Connecticut river. Its northernmost recorded locality is Milford, N. H., very rare (Whitney).

68. *Ancyloxypha Numitor* Feld. In New England this smallest of our butterflies is abundant south of the latitude of 42° 30′, but has been recorded from only a single locality north of it, Milford, N. H. As it is said to be common there, it will probably be found somewhat farther north.

69. *Amblyscirtes vialis* Scudd. In New England this butterfly is strictly limited to the southern half, having been found but once north of Massachusetts, at Milford, N. H. (Whitney).

70. *Amblyscirtes Samoset* Scudd. In New England it is found in such northern and elevated localities as Norway, Me., and the valleys of the White Mountains. It has also been taken at Milford, and once only in Massachusetts.

71. *Cyclopides Mandan* Scudd. In New England this butterfly has been taken but twice,—once in Norway, Me. (Smith), and once in the Glen, White Mountains (Sanborn).

72. *Ocytes Metea* Scudd. This is another of the many southern butterflies, whose northernmost known limit is Milford, N. H.

73. *Poanes Massasoit* Scudd. Excepting in New England this butterfly has not been taken north of Albany; in New England, although otherwise confined to the more southern portions, and especially to the lower levels, it has been taken at Milford, N. H.

74. *Atrytone Zabulon* Scudd. This common butterfly is taken throughout New England, in the southern parts of which it is exceedingly abundant. It is even common in such northern and elevated localities as Williamstown, Mass., Norway, Me., and Thornton and Plymouth, N. H.; it extends to Quebec and Nova Scotia.

75. *Pamphila Sassacus* Kirb. This butterfly occurs everywhere in the southern half of New England, but, excepting at Norway, Me., has not been taken in the northern half. Mr. Whitney has found it at Milford.

76. *Anthomaster Leonardus* Scudd. This butterfly also is confined in New England to the southern half, the northernmost localities from which it is recorded being Dublin (Faxon) and Milford, N. H. (Whitney).

77. *Polites Peckius* Scudd. In New England it is everywhere the commonest of the Astyci, and is found throughout every portion of the district, from the White Mountains to the sea-coast.

78. *Hedone Ætna* Scudd. It is found in the southern half of New England; once, however, a specimen was taken in Norway, Me. With that exception, its northernmost range is indicated by its capture in Walpole and Milford, N. H.

79. *Limochores Mystic* Scudd. It is found everywhere in New England, from the White Mountains to Cape Cod and New Haven. There is hardly a local collection of any size that does not contain it.

80. *Limochores bimacula* Scudd. It has seldom been taken in New England, and never north of Massachusetts, except at Milford, N. H., where it is rare.

81. *Limochores Manataaqua* Scudd. In New England it has been found only in widely separated localities. Among these, and one of the most northern, is Walpole, N. H., where Mr. Smith found it somewhat common.

82. *Limochores Taumas* Scudd. This butterfly is found over perhaps a larger extent of territory than any other species of its tribe. In New England it is everywhere common, from the White Mountains, and even from its highest altitudes, to the southern and eastern sea-coast.

83. *Euphyes Metacomet* Scudd. This insect is widely spread in New England, although it has been taken but rarely in its northern half; it has been taken at Norway, Me., and Thornton, N. H., and is not uncommon at Plymouth, Walpole, and Milford. South of these latter points it is everywhere rather common and sometimes abundant.

84. *Euphyes verna* Scudd. In New England it is confined to the Alleghanian region, and is everywhere exceedingly rare. A single specimen has been taken at Milford by Mr. Whitney.

85. *Lerema Hianna* Scudd. This member of the Alleghanian fauna has thus far been detected in New England in only a few localities. It is confined to its southern portions, but has been found to be somewhat common at Milford by Mr. Whitney.

III. List of the Orthoptera of New Hampshire, with Notes on their Geographical Distribution and Stridulation.

In the following pages I have given a list of all the species known to

me to inhabit the state, adding notes upon their geographical distribution both within and without the state. Such information is given concerning the mode and character of their stridulation as could be obtained. Unfortunately most of the material for the list has been collected about the White Mountains only in excursions made by my friends and myself. This accounts for its poverty.

GRYLLIDES.

1. *Gryllotalpa borealis* Burm. [Plate A, Fig. 7.] The northern mole-cricket inhabits nearly the whole of the United States east of the great plains, from Louisiana to Massachusetts. It has not yet been discovered in New Hampshire, but it will doubtless be found in the southern portions of the state, as it is not at all uncommon in the region about Boston and Springfield, Mass., and has been taken by Prof. Verrill, at Anticosti. The figure has been introduced upon the plate, to call the attention of those interested, and because it is one of the most peculiar forms among Orthoptera. It is a burrowing insect, as the character of the forelegs readily indicates. At Winter pond, Winchester, Mass., the whole surface of the ground beneath the sod and stones for a rod from the water's edge is completely honeycombed with their burrows. They seldom penetrate to a depth of more than six or eight inches, rarely to a foot beneath the surface. The burrows are usually about a third of an inch in diameter, entirely irregular in direction, and often terminate abruptly. Where the ground is hard the burrows are brought so near the surface as to raise long ridges of mould, which, when dry, frequently fall in and expose the burrows. The note of this insect is most frequently heard at dusk, and resembles the distant sound of frogs, but is somewhat feebler.

2. *Gryllus luctuosus* Serv. This insect is readily distinguished from all other species of the genus found in this part of the country by the great length of the wings, which extend far beyond the body and the elytra. It has been taken in New Hampshire by Mrs. F. W. Putnam, and is not infrequent even so far north as the valleys of the White Mountains. The individuals from this locality are much smaller than farther south.

Other species of this genus doubtless occur in New Hampshire, but I do not happen to possess specimens for determination. At Jefferson, in 1867, no chirp of a Gryllus was heard until August 12, although they often commence their song in Massachusetts in June.

3. *Nemobius vittatus* Harr. is found all over the state, even in the White Mountain region, and extends west as far as Nebraska, and south at least to Maryland. It appears a little earlier than the species of Gryllus, but in the White Mountains not until August. Its chirp is very similar to that of Gryllus, and can best be expressed by *ru* or *rruu*, pronounced as

Fig. 48.

Note of Nemobius vittatus.

though it were a French word. The note is trilled forcibly, and lasts a variable length of time, sometimes for several seconds; at others it is reduced to a short, sharp click.*

I once observed one of these insects singing to its mate. At first the song was mild, and frequently broken; afterward it grew impetuous, forcible, and more prolonged; then it decreased in volume and extent till it became quite soft and feeble. At this time the male began to approach the female, uttering a series of twittering chirps; the female ran away, and the male, after a short chase, returned to his old haunt, singing with the same vigor as before, but with more frequent pauses; at last, finding all persuasion unavailing, he brought his serenade to a close. The pauses of his song were almost instantly followed by a peculiar jerk of the body; it consisted of an impulsive movement backward, and then as suddenly forward, and was accompanied by a corresponding movement of the antennæ together, and then apart. The female was near enough to be touched by the antennæ of the male during the first movement, and usually started in a nearly similar way as soon as touched.

The elytra of the male are held at an angle of about twenty degrees from the body during stridulation, and, perhaps, at a slightly greater angle from each other. Even when most violent, the sound is produced

* It is necessary for me to describe the peculiar system of musical notation which I have adopted. Each bar represeots a second of time, and is occupied by the equivalent of a semibreve; consequently a quarter note ( ) or a quarter rest ( ) represents a quarter of a second; a sixteenth note ( ) or a sixteenth rest ( ) a sixteenth of a second, etc. For convenience' sake, I have introduced a new form of rest (or), which indicates silence through the remainder of a measure.

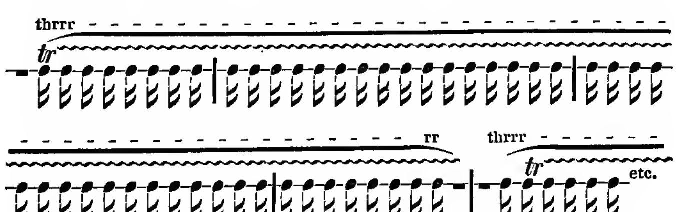
by the friction of the inner edges of the elytra only, not by the whole surface.

4. *Nemobius fasciatus* Scudd. This cricket may prove to be only a long-winged form of the preceding, as it scarcely differs from it in anything but the length of these organs. It is also found throughout New Hampshire, even in the White Mountain region. It occurs as far south as South Carolina, Louisiana, and Texas, and west at least to Missouri. I have not noticed any difference between the chirp of this species and of the preceding.

5. *Œcanthus niveus* Serv. is probably found in the southern portions of the state, although no record of its occurrence has fallen under my notice. It is certainly found in the neighboring parts of Massachusetts. This insect does great damage to young shoots of raspberry, blackberry, and even of the grape-vine, by depositing its eggs within the stem; these are laid in a nearly perpendicular row, often a foot long, at short distances apart, a single egg being introduced through each hole into the very heart of the stem, weakening it to such a degree that it is apt to break in a strong wind. A European species, thought by some to be identical with this, has a slightly different habit, and is far less, if at all, injurious. It makes its punctures much farther apart, and introduces two or three eggs into each opening.

The day-song of this insect is exceedingly shrill, and may be represented by the following figure, though the notes vary in rapidity. When

Fig. 49.

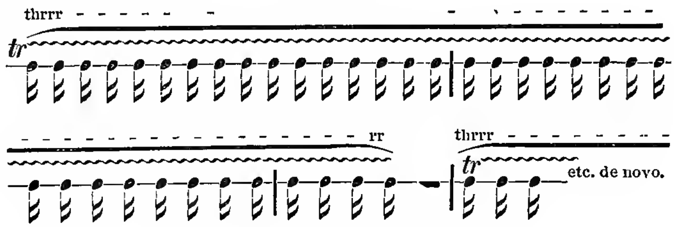


Note of Œcanthus niveus by day.

slowest they are about sixteen a second. The song is of varied length, sometimes lasting but two or three seconds, sometimes continuing a minute or two uninterruptedly; it is a nearly uniform, equally sustained trill, but the insect often commences its note at a different pitch from the normal one, as if it required a little practice to attain it. When singing,

the tegmina are raised at fully a right angle to the body. The night-song consists of *thrrr* repeated incessantly, three parts of song and one of rest in every three seconds.

Fig. 50.



Note of Œcanthus niveus by night.

LOCUSTARIÆ.

6. *Ceuthophilus maculatus* Scudd. is found throughout New England and as far south as Maryland. I once took a specimen half way up Mt. Washington. All the Vermont specimens I have seen are unusually dark.

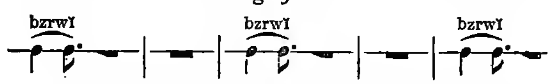
7. *Phylloptera oblongifolia* Burm. has not been found in the state, but as it occurs somewhat abundantly in Massachusetts, and is found as far west as Iowa, it doubtless inhabits at least the southern part of New Hampshire. I have not studied its note attentively, but if I recollect aright, it gives three rapid notes in succession like the katydid.

8. *Phaneroptera curvicauda* Serv. This insect is found all over the state, even inhabiting the sub-alpine zones of the White Mountains. It is found also as far south as the Carolinas, and west to the Red river settlements of British America, to Michigan, and Illinois. It is more noisy by night than by day; and the songs differ considerably at these two times. The day-song is given only during sunshine, the other by night and in cloudy weather. I first noticed this while watching one of these little creatures close beside me; as a cloud passed over the sun, he suddenly changed his note to one with which I was already familiar, but without knowing to what insect it belonged. At the same time, all the individuals around me whose similar day-song I had heard, began to respond with the night cry: the cloud passed away, and the original note was resumed on all sides. Judging that they preferred the night-song to that of the day, from their increased stridulation during the former period,

I imitated the night-song during sunshine, and obtained an immediate response in the same language. The experiment proved that the insects could hear as well as sing.

This species is exceedingly shy, and the observer must be patient who would hold converse with it. One insect which I had disturbed, and beside which I was standing, could not at first decide to resume his song; he was afraid of the intruder, but, enticed by a neighboring songster, gave

Fig. 51.

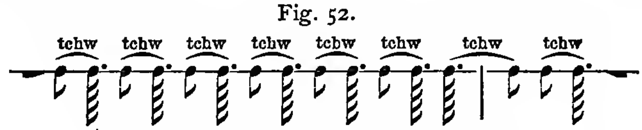


Note of Phaneroptera curvicauda by day.

utterance several times to a barely discernible, short click or *tĭ;* after five or six of these efforts his desires overcame his fears. The note by day is *bzrwĭ,* and lasts for one third of a second.

The night-song consists of a repetition, ordinarily eight times, of a note which sounds like *tchw.* It is repeated at the rate of five times in

Fig. 52.



Note of Phaneroptera curvicauda by night.

three quarters of a second, making each note half the length of the day note.

9. *Conocephalus ensiger* Harr. Found throughout New England, even into the sub-alpine zone of the White Mountains; it extends south as far as the middle states and southern Illinois, and west to Nebraska, Minnesota, and the Red river of the north. Mr. Smith found a female of this insect "with the ovipositor forced down between the root-leaves and the stalk of the *Andropogon,* where the eggs are probably deposited."

There is a species of Conocephalus (*C. robustus* Scudd.), found on the southern sea-beaches of New England, which is exceedingly noisy, and sings equally, and, I believe, similarly, by day and night. The song resembles that of the harvest fly, *Cicada canicularis.* It often lasts for many minutes, and seems, at a distance, to be quite uniform; on a nearer approach, one can hear it swelling and decreasing in volume, while there

is a corresponding muscular movement from the front of the abdomen backward, two and a half times a second. This is accompanied by a buzzing sound, quite audible near at hand; it resembles the humming of a bee, or the droning of a bagpipe.

C. ensiger also seems to have a single song, but it stridulates only by night or during cloudy weather; it commences its song as soon as the sky is obscured or the sun is near the horizon; it begins with a note like *brw*, then pauses an instant and immediately emits a rapid succession of sounds like *chwĭ* at the rate of about five per second, and continues them for an unlimited time. Either the rapidity of the notes is variable, becoming sometimes as frequent as twenty-three in three seconds, or else there is some deceptive character in its song. In a number of

Fig. 53.

Note of Conocephalus ensiger.

instances I have counted the notes as rapid as the highest rate given above, but on a nearer approach to verify them the rate was invariably reduced to five per second; it is doubtful whether this was due to alarm at my approach, for this is the least shy of all our Locustarians.

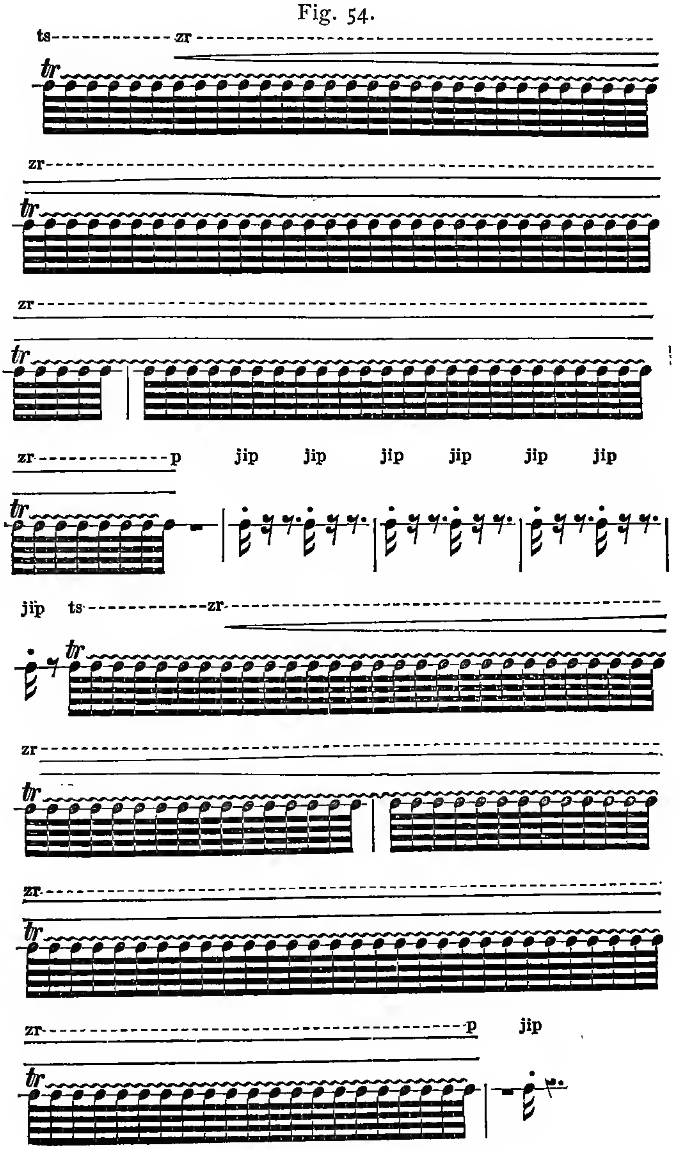
10. *Xiphidium fasciatum* Serv. It is found from the valleys of the White Mountain region southward, as far as Maryland and southern Illinois. Its note resembles that of Orchelimum, but is exceedingly faint.

11. *Xiphidium brevipenne* Scudd. This species has much the same distribution as the preceding, but is not recorded from points so far south, although it reaches Pennsylvania and Michigan. One year its first appearance was recorded about Boston, July 16th; another year in the neighborhood of Jefferson, White Mountains, August 8th.

12. *Orchelimum vulgare* Harr. This insect is found through all the White Mountain region, even to the alpine zone, and also over the rest of the state. It is everywhere very abundant, as its name indicates. It is also found southward at least as far as Maryland and southern Illinois, probably also to the Carolinas. There is not so great disparity in the time

of its appearance in the White Mountain region and in southern New England, as in some other species. One year it appeared in Jefferson, July 28, and the following year about Boston, July 15.

Fig. 54.



Note of Orchelimum vulgare.

Its song is more complicated than that of our other Locustarians. Commencing with *ts*, it changes almost instantly into a trill of *zr;* at first

there is a crescendo movement, which reaches its volume in half a second; the trill is then sustained for a period varying from one to twenty seconds (generally from six to eight seconds), and closes abruptly with *p*. This strain is followed by a series of very short staccato notes sounding like *jip!* repeated at half-second intervals; the staccato notes and the trill alternate *ad libitum*. The staccato notes *may* be continued almost indefinitely, but are very rarely heard more than ten times in succession; it ordinarily occurs three or four times before the repetition of the phrase, but not more than two or three times when the phrase is not repeated. I have known it to be entirely omitted, even before the repetition of a phrase. The interval between the last *jip!* and the recommencement of the phrase never exceeds one quarter of a second. The night-song differs from that of the day in the rarer occurrence of the immediate notes and the less rapid trill of the phrase; the pitch of both is at B flat.

13. *Thyreonotus dorsalis* Scudd. I have taken a single specimen of this insect as far north as Sudbury, Vt.; and since it also occurs in eastern Massachusetts, it will no doubt be found within the limits of New Hampshire in the Connecticut valley.

ACRYDII.

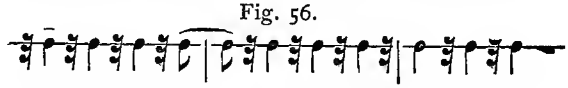
14. *Chloealtis conspersa* Harr. This is a northern insect, extending from Maine to Lake Winnipeg, and is found all over New Hampshire, even in the valleys of the White Mountains. South of the state it occurs on

Fig. 55.

Note of Chloealtis conspersa in the sun.

high lands. The male differs so much in appearance from the female that I formerly described it under a distinct generic name. Its song is

Fig. 56.



Note of Chloealtis conspersa in the shade.

of varied rapidity, according to the amount of sunshine; in the sun it makes from nine to twelve notes, at the rate of fifty-three in fifteen seconds; the usual number of notes is ten.

In the shade the rate falls to forty-three in fifteen seconds, the number of notes remaining the same.

The femur is evidently scraped gently upon the elytron to produce the sound, for frequently, at the commencement, two or three noiseless movements are made, the leg failing to touch the wing-cover. I once found three males singing to a single female, who was busily engaged laying eggs in a stick of wood, her abdomen plunged into a hole she had bored to the depth of half an inch; two of the males were near enough each other to cross antennæ.

Mr. S. I. Smith gives an interesting account of the habits of this species in the *Proceedings of the Portland* (Me.) *Society of Natural History*.

The eggs are deposited in old logs, in the under sides of boards, or in any soft wood lying among the grass which these insects inhabit. By means of the anal appendages, the female excavates in the wood a smooth, round hole, about an eighth of an inch in diameter. This hole is almost perpendicular at first, but is turned rapidly off in the direction of the grain of the wood, and runs nearly parallel with, and about three eighths of an inch from, the surface,—the whole length of the hole being an inch or an inch and a fourth. A single hole noticed in the end of a log was straight. The eggs, which are about a fourth of an inch in length, quite slender, and light brownish yellow, are placed in two rows, one on each side, and inclined so that, beginning at the end of the hole, each egg overlies the next in the same row by about half its length. The aperture is closed by a little disk of a hard, gummy substance. I have seen many of the females engaged in excavating the holes, and they always stood with the body in the direction of the grain of the wood, and apparently did not change their position during the operation. When one was just beginning a hole, it was very easy to see the upper appendages rise and open, and each time scrape away a little of the wood. During this operation a frothy fluid is emitted from some part of the abdomen, but whether it serves to soften the wood, or to lubricate the appendages and the sides of the hole, I did not determine. There were always great numbers of half finished holes, or those just begun, and comparatively very few that were completed; and I have often found upon the under side of boards great numbers of the holes just begun, none of them being more than an eighth of an inch in depth. Perhaps the reason for so few holes being finished is, that the wood proves too hard, and the insect tries for a softer place, or, many of them may be disturbed during the operation. When they had opened the hole only to a slight depth, they leaped away if disturbed; but when the abdomen was quite a distance into the nearly completed hole, they seldom attempted to withdraw it even after the hand was upon them.

I have also noticed that this insect is not easily suited in choosing the

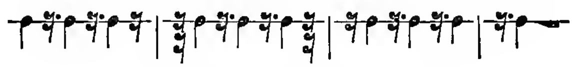
best place to bore her nest; the wood must be firm enough to retain the eggs well in place, and soft enough to absorb much moisture in the spring. Upright pieces of timber are never chosen, but rather short sticks of decaying, charred, or pithy wood, which cannot easily be broken or blown against the rocks. Holes are frequently made three quarters of an inch deep, and abandoned because the spot proves unsuitable. In a stick about a foot and a half long and two or three inches wide, I counted seventy-five borings, only three or four of which had been used as nests. The number of imperfect to perfect holes must be as twenty-five to one, or, perhaps, as fifty to one. When a good piece of wood is discovered, the nests are crowded thickly together; and a stick less than two inches in diameter and five inches in length contained thirteen completed nests. The holes are pierced at a slight angle to the perpendicular, away from the insect; they are straight for about a quarter of an inch, then turn abruptly and run horizontally along the grain for about an inch. The eggs (from ten to fourteen in number) are almost always laid in the horizontal portion of the nest; they are cylindrical, tapering toward the ends, but not at all pointed, and measure from five to five and a half millimetres in length, by one and one eighth in breadth; the ends are equally and regularly rounded. They vary in tint, some being almost colorless, and others of a faint yellow. After the eggs have been carefully packed away in the sawdust made by the abrasion of the sides of the hole, they are covered above with a whitish froth, and the hole is sealed up just below the surface of the wood with a black glutinous secretion, excessively hard, smooth, and shiny, and the upper surface slightly concave. In the spring the moisture doubtless softens these coverings so that the young grasshoppers can easily escape. Many old nests may be found uncovered and filled with the shells of the eggs, but none in which the cover is still retained.

15. *Chrysochraon viridis* Thom. This grasshopper has been taken in southern New Hampshire; it has an extensive range, having been taken, according to Thomas, as far west as southern Illinois and Nebraska.

16. *Stenobothrus curtipennis* Scudd. A very common species all over the state and in the valleys of the White Mountains; it extends from Maine to the Red river settlements in British America, and thence southward to Pennsylvania, southern Illinois, Colorado, and Wyoming. It

inhabits uplands rather than moist grounds. When about to stridulate, these insects place themselves in a nearly horizontal position, with the head a little elevated; they then raise both hind legs at once, and grate the thighs against the outer surface of the elytra. The first one or two movements are frequently noiseless or faint. In sunny weather the notes

Fig. 57.



Note of Stenobothrus curtipennis.

are produced at the rate of about six a second, and are continued from one and a half to two and a half seconds. When the sky is overcast, the movements are less rapid.

17. *Stenobothrus maculipennis* Scudd. The range of this insect is similar to that of the preceding. It is found in the White Mountain valleys and all over the state. Also, westward as far as Minnesota, Wyoming, and Nebraska.

18. *Stenobothrus æqualis* Scudd. This insect is believed by Smith to be identical with the preceding, and may prove to be. It also occurs in the White Mountain valleys and in other parts of New Hampshire, and has been taken in Maine, Massachusetts, New York, the middle states, and Minnesota.

19. *Tragocephala infuscata* Harr. A wide-spread insect, not only found in every part of the state, including the valleys of the White Mountain region, and up at least to the sub-alpine zone, but reaching southward to North Carolina and Louisiana, and westward to Nebraska and Colorado.

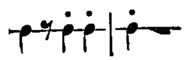
20. *Tragocephala sordida* Stål. This grasshopper is found in the southern half of the state, and extends from Maine, in the latitude of the White Mountains, to Maryland and Tennessee in the south, and Nebraska, Iowa, and Minnesota in the west. It has also been taken at London, Ontario, Canada.

21. *Arcyptera lineata* Scudd. This grasshopper has not been taken in the state, but, having been found at Norway, Me., Williamstown and Andover, Mass., it doubtless occurs here. It has also been taken in the valley of the Red river of the north.

22. *Arcyptera gracilis* Scudd. This insect is abundant at Jefferson

and other parts of the White Mountains, and is common on the summit of Graylock in Massachusetts; it has also been taken at Norway and other parts of Maine, and in Minnesota, and is abundant in the Red river settlements of British America. It is a very shy insect, but stridulates more loudly than other Acridians; its note can be heard at a distance of fifty feet. It usually makes four notes, but the number is sometimes greater. The first, a quarter of a second in length, is duller than the

Fig. 58.



Note of Arcyptera gracilis.

others, and is followed by a pause of a quarter second; the other notes are of the same length, but sharply sounded and follow each other rapidly.

23. *Pezotettix borealis* Scudd. This northern insect, originally described from Minnesota, the Saskatchawan river, Lake Winnipeg, and the Island of Anticosti, has since been mentioned from Speckled mountain in Stoneham, Me., and occurs also among the White Mountains. It is thought by some to be identical with *P. frigida* of northern Europe.

24. *Pezotettix manca* Smith. Described from a single specimen taken on Speckled mountain, Stoneham, Me.; doubtless, therefore, it will be found in the hilly parts of New Hampshire.

25. *Pezotettix glacialis* Scudd. [Plate A, Figs. 5, 10.] I have found this wingless Acridian most plentifully on Mt. Madison, the neighborhood of the snow-bank in Tuckerman's ravine, and at the ledge, all within the sub-alpine zone. In the latter place it frequents the branches of the small birch trees. I am not aware that any other of our Acridians are found habitually upon trees. I have found this species on Graylock (Berkshire county), Mass. Mr. Sanborn has taken it about the Umbagog lakes in northern Maine, and Mr. Smith on Speckled mountain, Stoneham, Me. Of this latter locality Mr. Smith says,—"It is in the southwestern part of Oxford county, and probably belongs to the White Mountain group. I am not aware that its height has ever been determined, but it is probably not much above two thousand feet. Upon the upper and treeless part of the mountain, where all the species of Pezotettix occurred [see the two preceding species], the following plants were abundant:

Alsine grœnlandica Fenzl., *Potentilla tridentata* Ait., *Vaccinium Vitis-Idæa* Linn., *V. uliginosum* Linn., *Empetrum nigrum* Linn."

26. *Melanoplus femur-rubrum* Stål. This species is wide-spread and destructive; it is found over all the portions of the United States lying east of the Rocky Mountains, excepting perhaps those bordering the Gulf of Mexico. In New Hampshire it ascends to the tops of the highest mountains, being common in both the alpine and sub-alpine zones. It has at times migrated in swarms like its congener, *M. spretus*, one of the most devastating of all insects. "The southern and western parts of New Hampshire," says Dr. Harris, in his treatise on injurious insects, "have been overrun by swarms of these grasshoppers, and have suffered more or less from their depredations." Dr. True gives the following account of their ravages in Pownal (Cumberland county), Me., about half a century ago:

During the haying season the weather was dry and hot, and these hungry locusts stripped the leaves from the clover and herds-grass, leaving nothing but the naked stems. In consequence, the hay crop was seriously diminished in value. So ravenous had they become that they would attack clover, eating it into shreds. Rake and pitch-fork handles, made of white ash, and worn to a glossy smoothness by use, would be found nibbled over by them if left within their reach.

As soon as the hay was cut, and they had eaten every living thing from the ground, they removed to the adjacent crops of grain, completely stripping the leaves; climbing the naked stalks, they would eat off the stems of wheat and rye just below the head, and leave them to drop to the ground. I well remember assisting in sweeping a large cord over the heads of wheat after dark, causing the insects to drop to the ground, where most of them would remain during the night. During harvest time it was my painful duty, with a younger brother, to pick up the fallen wheat heads for threshing; they amounted to several bushels.

Their next attack was upon the Indian corn and potatoes. They stripped the leaves and ate out the silk from the corn, so that it was rare to harvest a full ear. Among forty or fifty bushels of corn spread out in the corn-room, not an ear could be found not mottled with detached kernels.

While these insects were more than usually abundant in the town generally, it was in the field I have described that they appeared in the greatest intensity. After they had stripped everything from the field, they began to emigrate in countless numbers. They crossed the highway and attacked the vegetable garden. I remember the curious appearance of a large, flourishing bed of red onions, whose tops they first literally ate up, and, not content with that, devoured the interior of the bulbs, leaving the dry external covering in place. The provident care of my mother, who covered the bed

with chaff from the stable floor, did not save them, while she was complimented the next year for so successfully sowing the garden down to grass. The leaves were stripped from the apple-trees. They entered the house in swarms, reminding one of the locusts of Egypt, and, as we walked, they would rise in countless numbers and fly away in clouds.

As the nights grew cooler they collected on the spruce and hemlock stumps and log fences, completely covering them, eating the moss and decomposed surface of the wood, and leaving the surface clean and new. They would perch on the west side of a stump, where they could feel the warmth of the sun, and work around to the east side in the morning as the sun reäppeared. The foot-paths in the fields were literally covered with their excrements.

During the latter part of August and the first of September, when the air was still dry, and for several days in succession a high wind prevailed from the north-west, the locusts frequently rose in the air to an immense height. By looking up at the sky in the middle of a clear day, as nearly as possible in the direction of the sun, one may descry a locust at a great height. These insects could thus be seen in swarms, appearing like so many thistle-blows, as they expanded their wings and were borne along toward the sea before the wind; myriads of them were drowned in Casco bay, and I remember hearing that they frequently dropped on the decks of coasting vessels. Cart-loads of dead bodies remained in the fields, forming in spots a tolerable coating of manure.

27. *Melanoplus punctulatus (Caloptenus punctulatus* Uhl.). This insect having been taken in Maine and in central Vermont, must occur in parts of New Hampshire.

28. *Melanoplus bivittatus (Gryllus bivittatus* Say). One may find this insect almost anywhere in New Hampshire, perched on the huge leaves of *Inula Helenium* growing by road-sides. It occurs in the White Mountain valleys, and has a very wide distribution extending along the Atlantic coast from Maine to Carolina or Georgia, and westward to the Rocky Mountains, where, Thomas says, it "is found east of the range from New Mexico to Montana [and farther, for I have taken it on Lake Winnipeg, and Kirby took it in latitude 65°, or about Fort Simpson in Arctic America], and west of it from Salt lake north to the dead waters of Snake river; and, although it is not mentioned among the collections made in Washington territory, yet I am of the opinion it will be found there."

29. *Œdipoda carolina* Burm. This grasshopper is found through all the parts of the state included in the Alleghanian fauna, but no farther; it is found, for instance, at Shelburne, on the Androscoggin, but not in the Glen, or the upper valley of the Peabody. It is a wide-spread species,

reaching Georgia and Mississippi on the south, and extending westward to New Mexico, Colorado, Nebraska, Utah, Wyoming, and even, according to Walker, Vancouver's island, on the Pacific coast. It makes a muffled, rustling sound with its wings during a somewhat sustained flight.

30. *Hippiscus phœnicopterus* (*Œdipoda phœnicoptera* Germ.). Plymouth is the only place in New Hampshire in which I have taken this grasshopper, but it doubtless occurs in all the region south of the White Mountains, for it is found throughout the southern part of New England, and as far south as Carolina, and even Florida, and, according to Thomas and Walker, reaches Colorada, Dakota, and Nebraska.

31. *Hippiscus rugosus* (*Œdipoda rugosa* Scudd.). This grasshopper has not yet been captured in New Hampshire, but it undoubtedly belongs to the fauna of the state, having been taken in Norway, Me., upon one side, and Massachusetts on the other, and also, according to Thomas, in the distant regions of Nebraska, Dakota, and Missouri.

32. *Arphia xanthoptera* (*Œdipoda xanthoptera* Germ.). Extends from middle New Hampshire to Carolina along the Atlantic coast, and westward to the Mississippi.

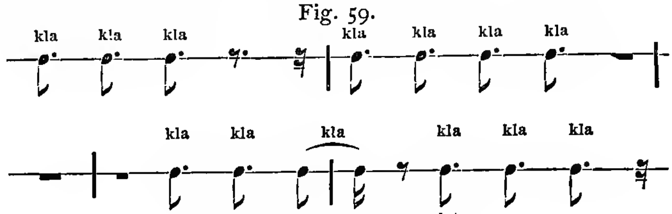
33. *Arphia sulphurea* Stål. Although this insect has never been recorded from New Hampshire, it doubtless inhabits the state, for it is found in Norway, Me., and is not at all uncommon in Massachusetts; it is, however, a southern insect, extending to Florida, and westward to Colorado, Missouri, and Nebraska, according to Thomas, and even, by Mr. Walker's statement, to Vancouver's island, on the Pacific coast.

34. *Trimerotropis æqualis* (*Gryllus æqualis* Say). This grasshopper is found at Norway, Me., and, as it occurs also in Vermont and Massachusetts, it must belong to the fauna of New Hampshire. According to Walker, it extends south to Florida; but I know of it from no point farther south than Long island. Westward, I have taken it at the Red river settlements and Minnesota, and it also occurs in Iowa, Dakota, and northern Illinois.

35. *Trimerotropis verruculata* (*Locusta verruculata* Kirb.). A very abundant species in the valleys of the White Mountains, as well as all over the state; it has also been taken on the top of Mts. Tom and Graylock in Massachusetts, in the northern wilds of Maine, on the Saguenay river in Canada, the region of the Saskatchawan river, and even in south-

ern Illinois, the only southern locality I know; at least, Mr. Thomas sent it to me from there: could he have received it from some other quarter? This insect, like the preceding, stridulates at will during flight; the flight is well sustained, and the insect is capable of changing its course. At each turn it accompanies the movement with a swoop-like curve, and

Fig. 59.



Note of Trimerotropis verruculata.

emits a crackling sound. In verruculata the sound is like *kl* or *kla*, the former at a distance, the latter nearer by; it is repeated at the rate of about five per second. Just before alighting, it crackles more rapidly and frequently.

36. *Trimerotropis maritima* Stål. This curious grasshopper is a good example of mimicry, for it so closely resembles the color of the sand on a sea-beach that it is difficult to see it when alighted. It is found only in such localities, and reaches its northern limits about the narrow part of the state washed by the sea. I have taken it at Hampton. Southward it extends at least as far as New Jersey.

37. *Camnula pellucida* (*Œdipoda pellucida* Scudd.) This insect is silent in flight, and is a northern species, swarming in immense numbers among the White Mountains and on the dry summits of the country south of it. The top of Mt. Prospect, near Plymouth, was covered with myriads of them in the autumn of 1873. It is found, however, as far south as Connecticut and southern Illinois, and west to the latter region and Lake Superior. It is very closely allied to *C. atrox* of the Pacific coast, which is said to be the most destructive grasshopper there, and to migrate in swarms like *Melanoplus spretus*.

38. *Tettix granulata* Scudd. This is a northern insect, occurring throughout the state, even into the valleys of the White Mountains. Southward it extends as far as the middle states, but is most common farther north; it occurs at Hudson's bay and about Lake Huron, and as far west as Minnesota. Kirby took it in Arctic America, as far north as lat. 65°, probably near Fort Simpson.

39. *Tettix ornata* Scudd. This more southern species is still found in New Hampshire, at least in the southern portion; other northern localities are Norway, Me., and Royalton, Vt. It extends southward as far as the District of Columbia, southern Illinois, and eastern Missouri.

40. *Tettix triangularis* Scudd. This species, which also occurs in southern New Hampshire, seems to have a distribution very similar to that of the preceding, having also been taken in Maine, and extending as far south as the middle states; it does not seem to have been noticed far west, but has been taken at Prescott, Canada West.

41. *Tettigidea lateralis* Scudd. Also a southern species, but found in southern New Hampshire, and in Maine as far north as Norway. Southward, it extends to Florida, and westward to southern Illinois and the vicinity of St. Louis.

42. *Tettigidea polymorpha* Scudd. The distribution of this species is apparently identical with that of the preceding. It is found in southern New Hampshire and in Maine as far as Norway, where it is said to be common; southward it is recorded as far as Alabama, and west to Prescott, Canada West, southern Illinois, and the vicinity of St. Louis, Mo.

43. *Batrachidea cristata* Scudd. This species has apparently a more limited range. It is recorded from New Hampshire, but from what portion of it is unknown; in Maine it has been taken in the centre of the state, and at Norway "on rocky hills." Southward it extends to the middle states, but is not mentioned from any point farther west.

PHASMIDA.

44. *Diapheromera femorata* Scudd. [Plate A, Fig. 3.] The walking-stick appears to be rare north of Massachusetts; it has, however, been taken in New Hampshire, and I have found it as far north as Sudbury, Vt., and even in the Red river settlements in British America. It has also been taken in Prescott, Canada West, and extends as far west as Nebraska, Kansas, and Iowa, and southward to Virginia, and, judging from poor specimens, from the farther parts of Texas. It lives mostly upon the lower branches of oaks, or on young trees of less than a man's height. The eggs are dropped loosely upon the ground, and do not hatch until the succeeding year, sometimes not until the second year.

BLATTARIÆ.

45. *Phyllodromia gennanica* Serv. This cosmopolitan pest, well known

as the "water bug," has been taken in New Hampshire; it undoubtedly reached this country from Europe.

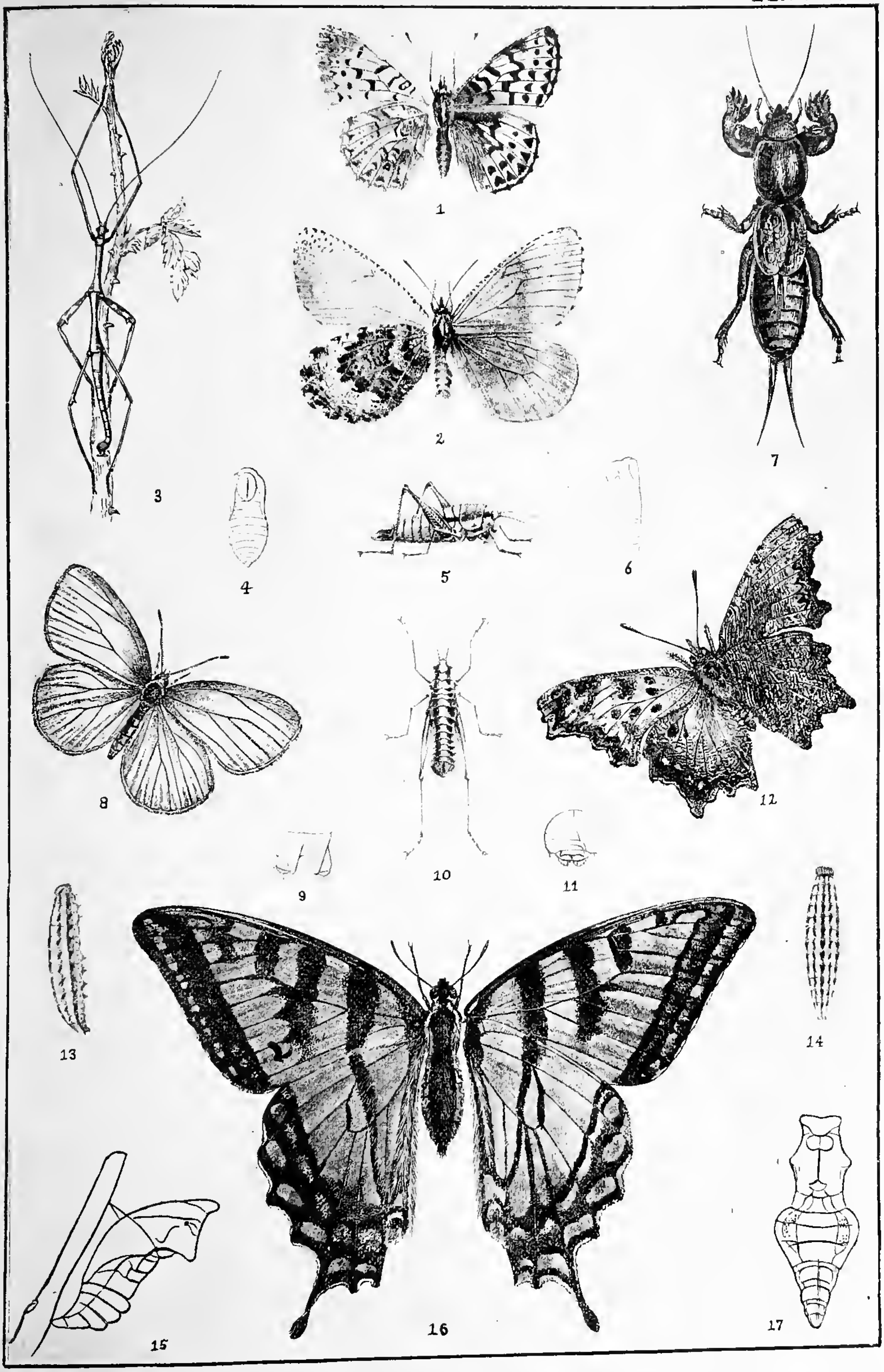
Doubtless other species of this family occur upon the seaboard, but none have been recorded.

FORFICULARIÆ.

46. *Labia minuta* Scudd. Smith records the capture of a number of specimens of this earwig at Norway, Me., and we may therefore conclude that it inhabits New Hampshire, for it occurs southwardly as far as Maryland, where Mr. Uhler found it in rotten fungi, and even Virginia. It has not been found west of the Atlantic states. Dohrn considers it identical with the European *L. minor.*

Explanation of Plate A.

Fig. 1. Brenthis Montinus.
" 2. Œneis semidea.
" 3. Diapheromera femorata.
" 4. Œ. semidea; chrysalis, dorsal view.
" 5. Pezotettix glacialis, side view.
" 6. Œ. semidea; chrysalis, side view.
" 7. Gryllotalpa borealis.
" 8. Ganoris oleracea.
" 9. Œ. semidea; hinder extremity of caterpillar, from above; enlarged.
" 10. P. glacialis, dorsal view.
" 11. Œ. semidea; front view of head of caterpillar; enlarged.
" 12. Polygonia Progne.
" 13. Œ. semidea; caterpillar, side view.
" 14. Œ. semidea; caterpillar, dorsal view.
" 15. Laertias Philenor; chrysalis, side view.
" 16. Euphœades Glaucus.
" 17. Laertias Philenor; chrysalis, dorsal view.



New Hampshire Insects.

CHAPTER XIII.

THE DISTRIBUTION OF PLANTS IN NEW HAMPSHIRE.

BY WILLIAM F. FLINT.

BOTANISTS divide the flora of the United States into several natural districts, while these are again subdivided. The district to which New Hampshire belongs is the great Middle and Northern; but with such marked difference, especially noticeable in our forest trees, between the northern and southern portions of the state, as to be most properly considered under two nearly equal divisions. Including also, as it does, the greater portion of the small alpine areas found within the eastern part of the United States, and comprising within its short range of sea-coast and the outlying Isles of Shoals a small part of the Maritime district, it presents to us a more interesting field for botanical research than any other area of equal size east of the Mississippi.

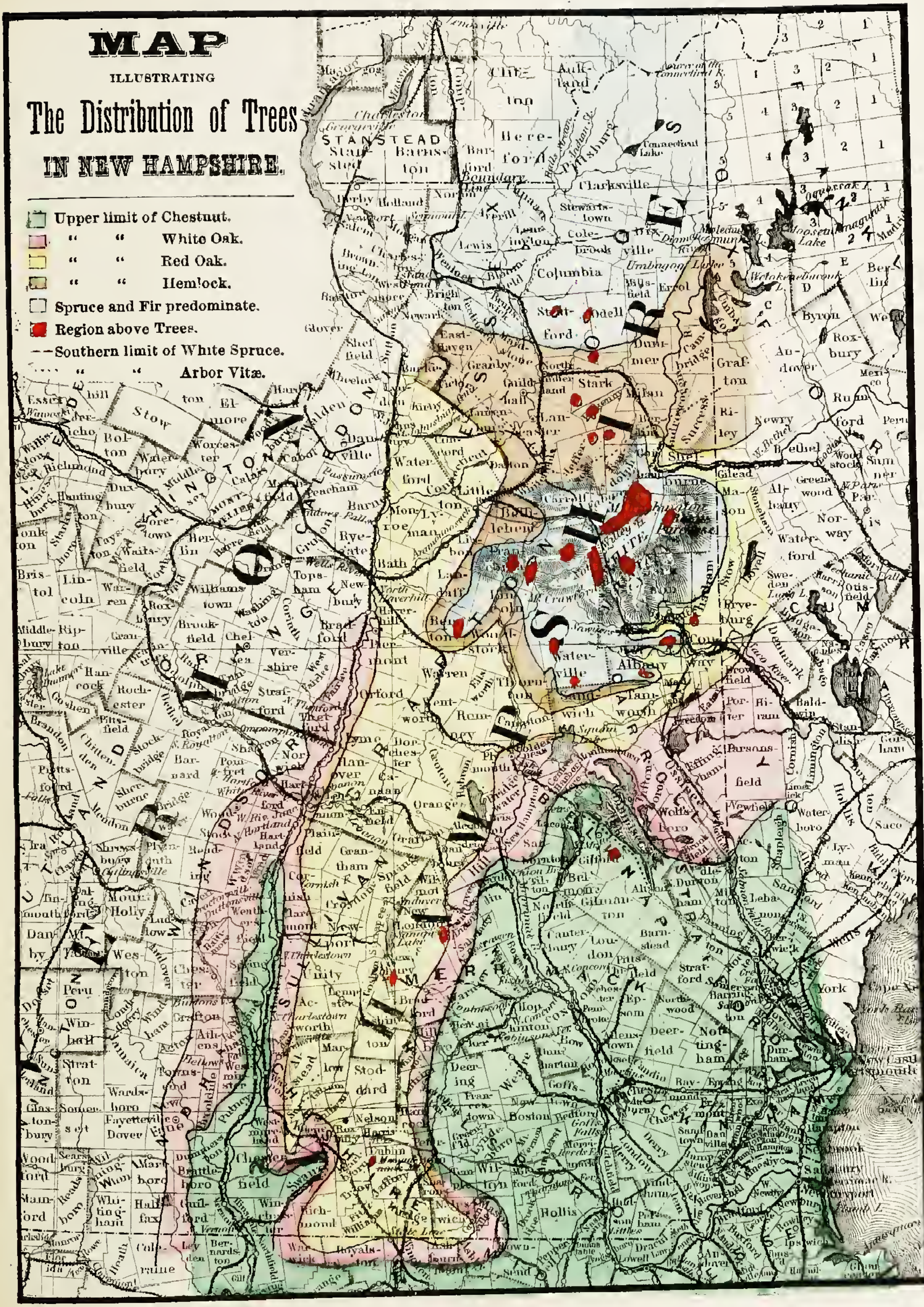
Originally the state, almost without exception, was clothed with a dense forest. This forest presented the same characteristics as at the present day. Its only change is that it has been greatly restricted in area by the hand of man. Its leading trees were pines, spruces, oaks, and hickories, the beech, chestnut, white, red, and sugar maples, the butternut, birches, elm, white and black ashes, basswood, and poplars. Among shrubs were the blueberries, the huckleberry, mountain ash, mountain laurel, azalea, alders, and willows; and, trailing over rocks and shrubbery, the wild grape, Virginia creeper, and virgin's bower.

A traveller, passing from one end of the state to the other, cannot fail

to observe the contrast in the aspect of the vegetation of its northern and southern portions, caused by the different temperature consequent upon the difference in altitude. The flora of New England has been classed in two divisions, based upon this fact, which may be termed the Alleghanian and the Canadian, because they seem to correspond with the faunas of the same names described in the previous chapter. Of course, however, no separating line, or definite and sudden change, is anywhere noticed. The transition is gradual, some species becoming scarce and finally disappearing, while others first appear in small numbers, but increase as the traveller advances, and at length supply the place of the former as the prevailing forms of vegetation. Many other species, probably one half in number of our whole flora (not being so readily influenced by a difference of temperature), have a range extending over the entire state. If it were attempted to draw the line between these divisions, on each side of which would of course be included species more particularly characteristic of the other, it might be extended, approximately, from North Conway to Lake Winnipiseogee, and thence to Hanover or vicinity. The transition area is thus at an elevation of about five or six hundred feet above the sea, corresponding approximately to the isothermal line of 45° mean annual temperature, or to 20° during the winter and 65° during the summer months.

Among the species which are characteristic of the Alleghanian division, but find their northern limit before reaching this line or soon after it is crossed, may be mentioned the chestnut, the white oak, spoonwood or mountain laurel, and the frost grape (*Vitis cordifolia*). The range of our pines and walnuts, of white or river maple, red oak, and hemlock, is also mainly southern.

The most characteristic trees of the Canadian division are sugar maple, beech, balsam fir, black and white spruce, and arbor-vitæ; among its shrubs are the mountain and striped maples, and the mountain ash. Of these the white spruce and arbor-vitæ have the most limited range; the former is abundant about Connecticut lake, but occurs rarely, if at all, south of Colebrook; the latter, often incorrectly called "white cedar," is also common in this section, extending south to the vicinity of the White Mountains. It is also occasionally found in highland swamps farther south.


MAP
ILLUSTRATING
The Distribution of Trees
IN NEW HAMPSHIRE.
Upper limit of Chestnut.
" " White Oak.
" " Red Oak.
" " Hemlock.
Spruce and Fir predominate.
Region above Trees.
Southern limit of White Spruce.
" " Arbor Vitæ.

A map has been prepared, illustrating this distribution in the case of some of our forest trees. The lines there drawn will be seen to agree nearly with contour lines having the altitudes which are mentioned in our further notice of these species. Thus the greater altitude of the highlands in the southern part of the state, between the Merrimack and Connecticut, excludes chestnut and white oak, and gives to that section a flora like that of the southern part of the Canadian division.

Forest Trees.

Among the twenty-seven natural orders which make up the greater part of the flora of New Hampshire, we find the pine family the most important, either as a prominent feature of the landscape, or as contributing to the wealth of the state. First in this family is the white pine, which has been the most valued of our forest trees ever since the servants of King George roused the indignation of the pioneers by placing their "broad arrow" on the best mast trees of the Merrimack valley. When the country was covered by the primeval forest, this tree filled all the river valleys with a stately growth, extending along that of the Connecticut to the northern boundary. At the present day this growth has nearly disappeared before the lumberman's axe, but the great abundance of saplings in the southern part of the state shows that this species is still the principal conifer of that section. Passing northward into Coös county, we find the white pine much restricted in area, occurring mostly at the head waters of the streams, and mainly confined to first growth specimens, saplings being of rare occurrence, even where the land is allowed to return to forest after clearing.

The pitch and red pines are much more limited in range than the foregoing. The pitch pine finds its most congenial soil along the sandy plains and drift knolls of the river valleys, scarcely growing on hills that attain much elevation above the sea level. It is found most abundantly in the south-eastern part of the state, in the Merrimack valley, and around Lakes Winnipiseogee and Ossipee, extending northward as far as North Conway. In the valley of the Connecticut it appears less abundantly. The red pine, often wrongly called "Norway pine," is the most social of the pine genus found with us, occurring in groups of from a few individuals to groves containing several acres. Although much less

common, its range is nearly the same as that of the pitch pine, probably attaining a higher elevation above the sea level. This species is of handsome appearance and rapid growth, and is well worthy to be planted for ornament.

In the White Mountain region, the balsam fir and black spruce, growing together in about equal numbers, give to the scenery one of its peculiar features. The stiff, spiked forms of the one are mingled with the blackish green foliage of the other almost universally along the mountain sides, and are the last of arborescent vegetation to yield to the increased cold and fierce winds of the higher summits. North of the mountains these trees, with arbor-vitæ, are the predominant evergreens, mingling with the white spruce about Connecticut lake. In the southern part of the state they are mostly confined to the highlands between the Merrimack and Connecticut, the black spruce appearing most abundantly.

The hemlock, which when young is the most graceful of the spruces, is common in the southern part of the state, ranging in greatest abundance from around the base of the White Mountains southward along the highlands, becoming less common near the coast. It has its northern limit in the vicinity of Colebrook and Umbagog lake, reaching an elevation of about twelve hundred feet above the sea.

"Our arbor-vitæ is," says Prof. Gray, "the physiognomic tree of our cold swamps at the north and in Canada." This tree, very rarely seen in southern New Hampshire except when cultivated for a hedge,* enters as a prominent element into the flora of Coös county, growing most abundantly along the borders of slow streams and in swamps, and varying from thirty to fifty feet in height.

Hackmatacks, or tamaracks, do not enter largely into our flora, but are of very graceful appearance wherever they are seen. This species is chiefly found in swamps of small extent, and ranges along the highlands from Massachusetts to north of the White Mountains. The red cedar, or savin, has the most limited range of all our trees belonging to this family, occurring mostly near the sea-coast in sterile soil.† Juniper, of the same family, is sometimes troublesome by overspreading hilly pastures. The Canadian variety of the yew is often present in cold

* Seen commonly in Sutton, Windsor, Antrim, and probably other towns along the Connecticut-Merrimack water-shed.—C. H. H.

† Occurs also in Hart's Location.—C. H. H.

land swamps as an under shrub, familiarly known by the name of "ground hemlock."

While the evergreens wear the same sombre aspect throughout the year, the deciduous trees present every phase of change, from leafless branches in winter to the delicate green of spring, the full leafage of summer, and the gorgeous hues of autumn; so that to them are due some of the most pleasing features of New Hampshire scenery. This effect is increased by their greater number of species as compared with the evergreens, and by their heterogeneous mode of growth, a forest of deciduous trees generally containing several species, growing in about equal numbers. In our forests the most important of these are maples, beech, birches, chestnut, and oaks; and, less abundantly, elm, butternut, hickory, ashes, cherries, basswood, and poplars.

The maples are best represented, all the species growing in the northern United States being present. First among these are our white, red, and sugar maples, all being large trees. The white or river maple is the most limited in range, being confined to the intervals of the principal streams, and rarely found away from them. The red maple (often wrongly called white maple) is the most widely spread species, being common to all parts of the state, and giving the brilliant scarlet hue of our woodlands in autumn. The rock or sugar maple is the largest of the genus, and fills an important part in the economy of the state, furnishing sugar and valuable timber. It is common on hillsides throughout most of the state and along many of the streams, but is rare toward the sea-coast.

The beech and the sugar maple are the most common deciduous trees of Coös county, making up the greater part of the "hardwood" forests. Southward, beech is common to the highlands only, often growing with spruces and hemlocks.

Four species of birch are common. Three of them,—the black, yellow, and canoe birches,—have the same range as the red maple, for the most part; but the canoe or paper birch seems to attain the highest elevation, being found high up the sides of the mountains, its white bark in striking contrast with the dark trunks and foliage of the firs and spruces. The fourth and smallest of these, the white birch, is distinguished for its light and graceful foliage, which renders it a pleasing feature wherever it is

found. It is most abundant in the south-eastern part of the state, springing up along sandy plains and around the edges of woodland. Its growth is rapid, rising again, when cut down, by shoots from the root. This species supplies the "gray birch hoop-poles" used in the manufacture of fish barrels.

Five or six species of oaks are found here. Of these the red oak is the hardiest, but, although the only species found along the water-shed between the Merrimack and Connecticut, it does not extend much beyond the White Mountains, having its upper limit at about one thousand feet above the sea. The white and yellow oaks usually appear together, growing on the plains and hillsides along the rivers. The former of these, especially valuable for the strength and durability of its timber, extends northward in the Connecticut valley nearly to the mouth of the Passumpsic, in the Merrimack valley to Plymouth, and, in the eastern part of the state, to the vicinity of Ossipee lake. Its limit in altitude is about five hundred feet above the sea, which is also very nearly that of the frost grape. The barren or scrub oak is abundant on the pine plains of the lower Merrimack valley, thence extending eastward to the coast, and to the sandy plains of Madison and Conway. The chestnut oak seems to be local in this state; at Amherst and West Ossipee it can be found abundantly.

The chestnut is found in the same situations as the white oak, but is the first to reach its limit in altitude, which is at a height of about four hundred feet above the sea. It occurs in a few localities about Lake Winnipiseogee at a somewhat greater height, the neighborhood of the lake producing less severity of temperature than in the river valleys at the same altitude.

The American elm attains probably the largest size of any of our deciduous trees. This naturally finds its home in the alluvial soil of our rivers. It has also been the most extensively planted for shade and ornament of all our trees, excepting perhaps the sugar maple. Owing to its majestic appearance, it is very conspicuous wherever present, but the number growing together is generally small.

Butternuts also prefer the borders of streams, and, in the valley of the Pemigewasset, extend northward to the base of the mountains. Hickories are most common in the lower Merrimack valley, the shellbark

extending northward to the vicinity of Lake Winnipiseogee. Basswood is found mostly on highlands, but is not very common. The black cherry is found throughout the state, usually most common near streams.

Two species of poplar are commonly found. The first is a small tree, very common in light soil, and often springing in great abundance where woodland is cleared away. The other may be a large tree, with dark colored bark on the trunk, whence it is often called "black poplar." In spring the young leaves are clothed with white down, by which this species can then be distinguished at a great distance.

Shrubby Plants.

Next in order are shrubs, which, as an element of our flora, are much more abundant at the present day than formerly, when the shade of the dense forest restricted them to the borders of ponds and streams, the thin soil of rocky hillsides, or the openings made by the path of the whirlwind. The clearing away of the forest gave the conditions favorable to the growth of shrubby vegetation. Consequently we find in almost all uncultivated cleared lands a great variety, the beautiful flowers of some being much admired, while the fruit of others is eagerly sought.

Belonging to the rose family are several species important in our flora. In early spring the shadbush, or service-berry, is observed almost everywhere, bearing a profusion of snow-white blossoms. This is followed by the pigeon cherry, which, like the first, often becomes a small tree. The mountain ash flourishes along the mountain streams, and grows out of the crevices of the rocks on the mountain sides. The two spiræas, or hardhacks, are very common by roadsides and in pastures. The numerous blackberries and raspberries spring up abundantly in the same situations, and in newly cleared lands. The former are found mostly in the Alleghanian division, being less common north of the White Mountains, the red raspberry there replacing them, and being very characteristic of Coös county. In this genus is the flowering raspberry, popularly called "mulberry," with broad leaves and handsome rose-like flowers, often found in the Connecticut valley.

Growing in moist soil and along alluvial banks are the flowering dogwoods, or cornels, including several species. These bear white flowers in June, and clusters of red, blue, and white fruit in autumn.

The viburnums, or arrow-woods, seem as widely distributed as any of our flowering shrubs, and include the species familiarly known as arrow-wood, withe-rod, hobble bush, and cranberry bush. In June, the pure white flowers of the arrow-woods are very conspicuous in the thickets bordering meadows and along streams, while in the woods we find the hydrangea-like blossoms of the hobble bush. In the upper Connecticut valley the cranberry bush is common, and sometimes cultivated, the bright red fruit, which ripens after frosts, being used as a substitute for cranberries.

Belonging to the heath family we find, distinguished for beauty and abundance of bloom, the kalmias, or American laurels, azalea, rhodora, and clethra, and, barely entering within our limits, the stately *Rhododendron maximum*, or great rose bay, justly considered one of the finest of the heaths. The spoonwood or mountain laurel often forms dense thickets in the swampy woods of southern New Hampshire, its pink and white flowers and glossy leaves making it one of the most ornamental of our flowering shrubs. The little sheep laurel, much detested by farmers, because so prone to overrun pastures, generally appears with it, bearing a profusion of rose-red flowers. Along the edges of the woodlands and under evergreens, creeping close to the ground, grows the trailing arbutus or Mayflower, its pink and white fragrant flowers appearing among the first in spring. In cold upland woods throughout the state, overgrowing old logs and stumps, is found the *Chiogenes*, or creeping snowberry, its snow-white berries half hidden by the leaves. The pink azalea, common to the swamps of Cheshire county, is associated in the minds of many with the day when our legislature meets, being popularly called "election pink." Its almost flame-colored flowers appear about the first of June. This species readily bears transplanting, and is well worthy a place among cultivated ornamental shrubs. In moist land the rhodora is often found, rendered very conspicuous by its purple flowers, which appear before the leaves in early spring. The Labrador tea, bearing clusters of white flowers in June, is one of the low shrubs of bogs in Coös county. The clethra, with its racemes of sweet-scented white flowers, appearing in July and August, is found to some extent in the swamps along the Merrimack.

In the blueberry genus are included blueberries of several species, the

huckleberry, cranberry, and cowberry, the last of which is sub-alpine, and often called "mountain cranberry." Among the blueberries whose fruit is commonly gathered for market, the dwarf, or Pennsylvania blueberry, has the most extended range, being found far up the sides of mountains, and in the fields and pastures everywhere. The swamp, or high blueberry, is more limited, being common to the swamps and highlands southward, rarely appearing as far north as Conway. North of the mountains the Canadian blueberry is the representative species. The huckleberry is common in dry soil from the Merrimack valley eastward to the sea-coast. The common cranberry has nearly the same range as the high blueberry, a smaller fruited species appearing in Coös county.

Often met with in our swamps are the Canadian holly and winterberry, the latter well known for its crimson berries, persistent long after the leaves have fallen. In all our highland woods grows the handsome striped maple, and along rocky streams the scarcely less beautiful mountain maple. Sumacs delight in rocky situations on the southern slopes of hills, their purple autumn leaves and scarlet spikes of fruit being well known to all. Everywhere common is the alder, not only along the banks of sluggish streams, but extending along the marshy hollows of rough pastures. Seven or eight species of willows are commonly found, having a place in almost every variety of soil.

Herbaceous Plants.

The herbaceous plants occupy the largest place in any flora, as regards number and variety, a fact which is especially true of ours, the configuration of the state giving the conditions favorable to the growth of very numerous species. Among them are included the greater part of those which we term "wild flowers," and most of the introduced plants which have followed the settlement of the country. It is difficult to ascertain the limits of many of our herbaceous plants, as characteristic of the Alleghanian or Canadian divisions, for want of data bearing upon the subject.

The sea-coast, the Merrimack valley, and the vicinity of lakes Winnipiseogee and Ossipee, are our least elevated and longest settled portions; consequently, we there find our flora richest in species. The long belt of alluvial land of the Connecticut river also furnishes a field

favorable to the growth of many species of herbaceous plants; and to the presence of this river our Canadian division probably owes some species which would otherwise be wanting. A marked resemblance is seen also between the herbaceous flora of the water-shed between the Merrimack and Connecticut, and that at the base of the White Mountains.

It is regretted that the space of this article will permit the mention of but few of the great variety of herbs with which the hand of the Creator has made glad our fields and forests; but the book of Nature is ever open, and all who will may read. The vernal species, which attract the attention of the lover of nature, are mostly modest and delicate. Peering through the brown carpet of fallen leaves in our woodlands, we find in early spring the yellow violet, the dwarf ginseng, the yellow bellwort, trilliums, Solomon's seal, the frail blossoms of the bloodroot, and the hepatica, with its downy young leaves and white or sky-blue flowers.

A little later the shining leaves and yellow bells of the Clintonia show themselves beneath the shade of the hemlocks; and in the open glades nods the little wood anemone or wind-flower. In the crevices of ledges are found the early saxifrage and the wild columbine, popularly called "honeysuckle," whose curiously formed flowers swing in every passing breeze. The bright white flower of the false mitrewort appears in all marshy places. Violets are found in almost every kind of soil; and nearly every species of the Northern states finds its home in New Hampshire.

In upland woods we find, modestly trailing around the roots of moss-grown trees, the fragrant twin flower *(Linnæa borealis)*, whose botanical name was given in honor of Linnæus, who first discovered it in Lapland, and with whom it was an especial favorite. Growing in evergreen woods are four species of pyrola, or wintergreen, the prince's pine, Indian pipe, and pine sap. On the sandy plains toward the coast the wild lupine, blazing star, and butterfly-weed are not uncommon. In rich, moist places we find the jewel-weed, or wild balsam. Water lilies occur in all muddy streams and ponds, the yellow flowered species having a wide range and reaching to the alpine ponds of the White Mountains. In the rich meadows along the rivers grows the beautiful Canada lily, and the well known red lily is common to all pastures. The cardinal flower rears its flaming spikes along the brooksides in August. Springing up in great

profusion in newly cleared lands is the great willow-herb, with very showy bright purple flowers, whence it is often called "fire-weed." A great multitude of asters and golden-rods adorn our fields in late summer and early fall. Fringed gentians are almost the last flowers which appear in autumn, and are among the most admired of our wild flowers; they are not everywhere found, but may be sought for in meadows and along moist hillsides.

The orchis family attract the attention as the most beautiful and interesting endogenous plants in our flora. Many of them are rare, and most of them are limited in range. Among those well known to every one are the fringed orchises, two or three species being common in wet places; also, the little pink pogonia, and, in woodlands, the round-leaved orchis, with its shining leaves spread flat upon the ground. Under pines, we find the handsome stemless ladies' slipper; and, half hidden in the grass, in late summer, the little twisted spikes of the ladies' tresses.

The genus Carex, whose numerous species are commonly known as sedges, is the most fully represented of the endogens found with us, more than fifty species having been noted in New Hampshire. Although favorites with botanists, they are of little value to the farmer, the coarser species adding more in quantity than in quality to the hay mown from low, wet meadows.

Only two of the indigenous grasses of our state are of sufficient abundance to be of importance to agriculture. These are generally known as "white-top" *(Danthonia spicata)* and "blue-joint grass" *(Calamagrostis Canadensis)*, the former being most abundant in southern New Hampshire, while the latter is found throughout the state, and is the principal native grass of the upper Connecticut valley.

We find in the ferns the most graceful element, perhaps, of our flora, and these are very well represented, about forty species and varieties being known. Some of them are quite rare or local, being found only in obscure situations, and likely to be overlooked except by the keenest observer; but many of them abound in fields and woods, and are well known to most people. Among these the coarse fronds of the bracken, the plume-like Ostrich fern, and the more humble sensitive fern are very common. The beech fern is found fringing the mossy rocks of mountain brooks; and in the shade of the forest occur the taller spleenworts

and shield ferns, where also, clinging to moss-grown boulders, are the handsome evergreen fronds of the common polypody. The dwarf and ebony spleenworts and the frail bladder fern delight to find a lodgment in the crevices or at the base of perpendicular ledges.

Our state may be called the home of the Lycopodiums or club mosses, popularly known as "trailing evergreen," all excepting two of those belonging to the Northern states being present. They are found in deep woods and on cold, bleak hillsides, and are most common on the highlands of Cheshire county and around the base of the White Mountains.

The Alpine Flora.

The wind-swept summits of our White Mountains are to the botanist the most interesting locality east of the Mississippi, for there are found the lingering remnants of a flora once common probably to all New England, but which, since the close of the glacial epoch, has, with few exceptions, retreated to Arctic America. On the highest of these mountains, only, are found the conditions favorable to the growth of these arctic plants. Of these alpine areas, Mt. Washington and the adjacent peaks are the largest, being a treeless region at least eight miles long by two miles wide at its broadest part. These alpine plants are of great hardihood, and sometimes bloom amid ice and snow, as a Greenland sandwort, found in bloom on the summit of Mt. Washington by Mr. S. A. Nelson, March 11, 1871, well illustrates (p. 114). About fifty species are strictly alpine, and never found elsewhere with us. These are accompanied by about as many other species, which are also found at the base of the mountains, and sometimes throughout the state. These may be called sub-alpine, being found in the ravines and on the lower portions of the treeless areas, but not upon the higher summits.

The peculiar flora of these heights, almost wholly consisting of plants never found at lower elevations south of arctic latitudes, but identical with those found on Mt. Katahdin in Maine, and the Adirondacks in New York, has led naturalists to inquire how it is possible to account for this identity of species found at a few isolated stations in the midst of the temperate zone, with those of regions more than a thousand miles north. The conditions of climate which prevail over the intervening territory render it impossible for these plants to maintain their existence, and

Mt. WASHINGTON RANGE

show that they could never have migrated to these stations under ordinary causes. The science of geology has led to the probable solution of this problem. It has been found necessary, for the explanation of many phenomena in the surface geology of the northern temperate zone, to suppose that at a comparatively recent geological period the climatic conditions were wholly different from those of the present time. The ruins of a burned building do not tell their story more plainly than do the boulders of our hills and the worn and striated sides of our mountains prove the existence of glaciers and icebergs among them at no very distant date in geological history. The explanation which this affords of the origin of an arctic flora upon high mountains in the temperate zone, has been pointed out by one of the foremost theorists of the present day. As the low temperature of the frigid zone became gradually extended over this whole area, the forms of vegetation peculiar to an arctic climate took the place of those which had previously existed, while these receded to the south. Again, upon the gradual return of a more genial climate throughout this area, the arctic flora disappeared, following the retreat of the causes by which it was brought, and only remaining, with the reëstablishment of warmth and fertility, upon those higher mountain summits whose elevation renders them arctic islands in the middle of the temperate zone. He who ascends to this altitude has a similar opportunity for botanic study as if he made a journey to the north, passing first from the noble forests, with which we are familiar, to those of stunted growth, and, finally leaving them behind altogether, at length arriving at the barren and bleak regions beneath the Arctic Circle.

In approaching these mountain summits, one is first struck by the appearance of the firs and spruces, which gradually become more and more dwarfish, at length rising but a few feet from the ground, the branches spreading out horizontally many feet, and becoming thickly interwoven. These present a comparatively even upper surface, which is often firm enough to walk upon. At length these disappear wholly, and give place to the Lapland rhododendron, Labrador tea, dwarf birch, and alpine willows, all of which, after rising a few inches above the ground, spread out over the surface of the nearest rock, thereby gaining warmth, which enables them to exist in spite of tempest and cold. These in their turn give place to the Greenland sandwort, the diapensia, the cassiope,

and others, with arctic rushes, sedges, and lichens, which flourish on the very summits.

Introduced Plants.

As shown from field-notes, there are more than one thousand species of plants found in New Hampshire. Of these about one hundred are "introduced," having been imported, either intentionally or otherwise, through the agency of man. Some of them are indigenous in other parts of our own country, but the greater part come from Europe. Many of them have increased until they are found in all cultivated soils, while others establish themselves only locally. In the former class are most of the "weeds of cultivation," and nearly all the grasses mown for hay. Most of these plants, although so well established under the present conditions, would probably altogether disappear were the country allowed to return again to its natural state.

Unlike our indigenous species, these plants cannot be referred to any particular portion of the state, because, having been planted accidentally, they may be found regardless of altitude, &c., often in places where they would least be expected. An instance is seen in the garden wormwood *(Artemisia Absinthium)*, rarely seen outside of gardens in most places, but found well naturalized in Pittsburg, our most northern town, seeming to find in the soil derived from the slaty rocks of that region the conditions exactly suited to its growth. Instances of the wide range which some of our introduced species have attained, may be seen in the common hemp nettle *(Galeopsis Tetrahit)* and the herds-grass *(Phleum pratense)*. The former is common everywhere in the Merrimack valley, passing into the valley of the Connecticut through Franconia notch, and reaching northward to the clearings around Connecticut lake. The latter, cultivated for hay throughout the state, may be seen in the lumber roads throughout Coös county, and may even be traced up the carriage-road on Mt. Washington, far above the limit of trees.

The white willow of Europe *(Salix alba)*, which was at some time introduced for a shade tree, has extended itself along the rivers, evidently often without the aid of man, until now it may be seen as far north as Stewartstown in the upper Connecticut valley. The Canadian plum is much cultivated in Coös county, and may often be seen in places

where it cannot have been intentionally planted. The succory and the portulaca of the flower gardens seem likely to be added at some future time to our list of weeds of cultivation, the one as the companion of the ox-eye daisy, and the other with the common purslane.

Catalogue of the Plants of New Hampshire.

COMPILED FROM FIELD NOTES.

In making out the following catalogue, my acknowledgments are due to Dr. Nathan Barrows of Meriden, Rev. Joseph Blake of Gilmanton, Miss Mary Hitchcock of Hanover, Mrs. D. W. Gilbert of Keene, and Warren Upham of Nashua, for valuable field notes.

Explanation. A denotes Alleghanian, or southern; C, Canadian, or northern; M, mountain (alpine and sub-alpine); and S, sea-coast species. These letters italicized indicate that the species is strictly limited to the division noted. Species unmarked are likely to be found in any part of the state, but many of them are of rare occurrence. Those which are common almost everywhere, or in the division to which they belong, are marked by a star (*). Lowland species, which have extended upward to the mountain districts, are marked by a dagger (†). In some instances of rare or local plants, the towns in which they occur are mentioned below the name.

The botanic nomenclature is that of Gray's "Manual of Botany of the Northern United States," fifth edition, after which the popular names are also given. Italics denote introduced species.

CROWFOOT FAMILY.

Clematis verticillaris. . . . . *C*
North Conway.
C. Virginiana. Virgin's-bower. . . *
Anemone cylindrica. . . . . A
A. Virginiana. . . . . . *A
A. nemorosa. Wind-flower. . . *
Hepatica triloba. Liver-leaf.
H. acutiloba.
Thalictrum anemonoides.
T. dioicum. . . . . . †M
T. Cornuti. Meadow-rue. . . . *
Ranunculus aquatilis; var. trichophyllus.
R. multifidus.
R. Flammula; var. reptans.
R. Cymbalaria. . . . . . *S*
R. abortivus. . . . . *; †M
R. recurvatus. Crowfoot.
R. Pennsylvanicus.
R. fascicularis.
R. repens.
R. bulbosus.
R. acris. Buttercups. . . . *
Caltha palustris. { Marsh Marigold. "Cowslip." *C
Coptis trifolia. Goldthread. . . *
Aquilegia Canadensis. { Wild Columbine. "Honeysuckle." *
A. vulgaris.
Delphinium Consolida. Larkspur.
Actæa spicata; var. rubra. . . . *C
A. alba. Baneberry.
Cimicifuga racemosa.

MOONSEED FAMILY.

Menispermum Canadense.

BARBERRY FAMILY.

Berberis vulgaris. Barberry. . . *A*

Caulophyllum thalictroides. Cohosh.

Podophyllum peltatum. May-apple.

WATER-LILY FAMILY.

Brasenia peltata. Water-shield.

Nymphæa odorata. White water-lily. *

Nuphar advena. Yellow water-lily.* ; †M

* N. Kalmiana.

PITCHER-PLANT FAMILY.

Sarracenia purpurea. { Side-saddle flower. Pitcher-plant. } *A

POPPY FAMILY.

Papaver somniferum. Poppy.

Chelidonium majus. Celandine.

Sanguinaria Canadensis. Blood-root. A

FUMITORY FAMILY.

Dicentra Cucullaria.

D. Canadensis.

Corydalis glauca. . . . . . A

Fumaria officinalis. Fumitory.

MUSTARD FAMILY.

Nasturtium palustre. Marsh Cress. . *

N. *sylvestre.*

N. Armoracia. Horse-radish.

Dentaria diphylla. Pepper-root.

D. laciniata.

Cardamine bellidifolia. . . . *M*

C. hirsuta. Bitter Cress. . . . *

Arabis lævigata. Rock Cress.

Barbarea vulgaris. Yellow Rocket.
(Native in north-western U. S.)

Sisymbrium officinale. Hedge Mustard. *

Brassica nigra. Black Mustard.

B. campestris. Cale. . . . . *

Subularia aquatica.
Echo lake, Franconia; Gilmanton.

Capsella Bursa-pastoris. Shepherd's Purse. . . . . *

Lepidium Virginicum. Wild Pepper-grass. . . . . *A
(Introduced from southern U. S.)

Cakile Americana. Sea-rocket. . . *S*

Raphanus Raphanistrum. { *Wild Radish. Cale.* } *

VIOLET FAMILY.

Viola rotundifolia. . . . . . *C*

V. lanceolata.

V. blanda. White violet. . . . *

V. palustris. . . . . . . *M*

V. Selkirkii.

V. cucullata. Common blue violet. . *

V. sagittata.

V. canina; var. sylvestris. . *; †M

V. Canadensis. . . . . . . *C*

V. pubescens. Yellow violet. . . *

V. tricolor. Pansy.

V. renifolia, Gray.
Hanover; a new species.

ROCK-ROSE FAMILY.

Helianthemum Canadense. . . A

Hudsonia ericoides. . . . . . S
Conway, Concord.

H. tomentosa. . . . . . . *S*

Lechea major. . . . . . . A

L. thymifolia. . . . . . . S

L. minor. Pinweed. . . . . *A

SUNDEW FAMILY.

Drosera rotundifolia.

D. longifolia. Sundew.

ST. JOHN'S-WORT FAMILY.

Hypericum pyramidatum.
Charlestown.

H. ellipticum.

H. perforatum. Common St. John's-wort. . . . . *

H. corymbosum. . . . . . *

H. mutilum. . . . . . . *

* On Tuckerman's authority.

H. Canadense.

H. Sarothra. Pine-weed. *A

Elodes Virginica. Marsh St. John's-wort.

WATER-WORT FAMILY.

Elatine Americana. Water-wort.

PINK FAMILY.

Saponaria officinalis. { *Soapwort.* *"Old Maid Pink."* } *

Silene inflata.

S. Armeria.

S. antirrhina. Catchfly. . . . . A

S. noctiflora.

S. acaulis. Moss Campion. . . . *M*

Lychnis Githago.

Arenaria Grœnlandica. . . . *M*

A. lateriflora. Sandwort. . . . . *C*

A. peploides. . . . . . . *S*

Stellaria media. . . . . . . *

S. longifolia. Chickweed. Starwort.

S. longipes.

S. uliginosa.
Gilmanton, Concord.

S. borealis. . . . . . . †M

* S. nodosa.

Cerastium viscosum. Mouse-ear Chickweed. . . . . *

Sagina procumbens.

Spergularia rubra; var. campestris. } Sand-Spurrey. S
Claremont, Concord, Gilmanton.

S. salina. . . . . *S*

Spergula arvensis. Corn Spurrey.

Anchyia dichotoma.

Paronychia argyrocoma.
Willey house.] Whitlow-wort. †M

Scleranthus annuus. Knawel.

Mollugo verticillata. Carpet-weed. . *A
(Introduced from southern U. S.)

PURSLANE FAMILY.

Portulaca oleracea. Purslane. . . . *

P. grandiflora.

Claytonia Virginica. Spring Beauty. *A

C. Caroliniana.

MALLOW FAMILY.

Malva rotundifolia. Mallow. . . . *

M. sylvestris.

M. crispa.

M. moschata.

Abutilon Avicennæ.
Claremont.

Hibiscus Moscheutos. Rose Mallow. *S*

H. Trionum.
Claremont.

LINDEN FAMILY.

Tilia Americana. Basswood.

GERANIUM FAMILY.

Geranium maculatum.

G. Carolinianum. Cranesbill.

G. Robertianum. Herb Robert. . C

Erodium cicutarium. Storksbill.
Concord.

Impatiens pallida. C

I. fulva. Jewel-weed, or Touch-me-not. *

Oxalis Acetosella. Shamrock. . . *C

O. stricta. Wood-Sorrel. . . . *

RUE FAMILY.

Zanthoxylum Americanum. Prickly Ash.

CASHEW FAMILY.

Rhus typhina. } . . . . . . *
R. glabra. } Sumachs. . . . *
R. copallina. } . . . . . .

R. venenata. Poison Dogwood. . A

R. Toxicodendron. Poison Ivy. . *A

VINE FAMILY.

Vitis Labrusca. Wild Grape. . . *A*

V. æstivalis. . . . . . . *A*

V. cordifolia. Frost Grape. . . *A*

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* *Gray's Manual*, 1870.

Ampelopsis quinquefolia. { Virginia Creeper. "American Ivy." } *

BUCKTHORN FAMILY.

Rhamnus catharticus. Buckthorn. (Apparently indigenous at Richmond.)

R. alnifolius. . . . . . .

Ceanothus Americanus. New Jersey Tea. . . . . *A

STAFF-TREE FAMILY.

Celastrus scandens. Climbing Bitter-sweet. . . . . *A

SOAPBERRY FAMILY.

Staphylea trifolia.

Acer Pennsylvanicum. Striped maple. **C*

A. spicatum. Mountain maple. . . **C*

A. saccharinum. Sugar or Rock maple.*C

A. dasycarpum. White or River maple. *A

A. rubrum. Red maple. . . . *

MILKWORT FAMILY.

Polygala sanguinea. Milkwort. . . *

P. verticillata. . . . . . . A

P. Senega.

P. polygama. . . . . . . A

P. paucifolia. Fringed Polygala. . *

PULSE FAMILY.

Lupinus perennis. Wild Lupine. . **A*

*Trifolium arvense. Rabbit-foot clover.**A

T. pratense. Red clover. . . . . *

T. repens. White clover. . . . . * (Indigenous farther north.)

T. agrarium. Yellow clover.

T. procumbens. Claremont.

Melilotus officinalis. Claremont.

M. alba. Sweet clover.

Medicago lupulina. M. maculata. M. denticulata. { *Medick.*

Shore of Sugar river, Claremont, below Balcom's woollen mill. Introduced in foreign wool.

Medicago intertexta. Near stone paper-mill, Claremont.

Robinia Pseudacacia. Locust-tree. (Introduced from southern U. S.)

Desmodium nudiflorum. . . . *A

D. acuminatum. Tick-Trefoil. . . *A

D. rotundifolium.

D. Dillenii.

D. Canadense. . . . . . . *

D. paniculatum.

D. Marilandicum.

Lespedeza violacea. . . . . . A

L. hirta. Bush-clover. . . . *A

L. capitata. . . . . . . *A

Vicia sativa.

V. hirsuta. { *Vetch. Tare.*

V. Cracca.

Lathyrus maritimus. Beach Pea. . *S*

L. palustris. Marsh Vetchling.

Apios tuberosa. Ground-nut. . . A

Phaseolus perennis. Wild Bean. Claremont.

Amphicarpæa monoica. Hog pea-nut. *A

Baptisia tinctoria. Wild Indigo. . A

Cassia Marilandica. Wild Senna. . A

Gleditschia tricanthos. Honey-Locust. (Introduced from southern U. S.)

ROSE FAMILY.

Prunus Americana. Wild yellow plum.

P. pumila. Dwarf cherry. Campton.

P. Pennsylvanica. Wild red cherry. . *

P. Virginiana. Choke-cherry. . . *

P. serotina. Wild black cherry. . *

Spiræa opulifolia. Nine-bark.

S. salicifolia. S. tomentosa. { Meadow-Sweet, or Hardhack. *; †M *A

Agrimonia Eupatoria. Agrimony. . *

Geum album.

G. Virginianum.

G. macrophyllum. . . . . . *C*

G. strictum. Avens. . . . *

G. rivale. . . . . *C

G. triflorum. . . . . . . *C*

G. radiatum; var. Peckii. . . . *M*

Waldsteinia fragarioides.

Sibbaldia procumbens. . . . *M*

Potentilla Norvegica. . . . *

P. frigida. . . . . *M*

P. Canadensis. *
do. var. simplex.
Cinque-foil, or Five-finger.

P. argentea. . . . . . . *
P. arguta.
P. fruticosa. C
P. tridentata. . . . . . †M
P. palustris. . . . . . . *C*

Fragaria Virginiana. . . . . . *

F. vesca. Wild strawberry. . . *

Dalibarda repens. . . . . . *

Rubus odoratus. Purple flowering-raspberry. . . . . *

R. Chamæmorus. Cloud-berry. . *M*

R. triflorus. . . . . . . *

R. strigosus. Red raspberry. . . *

R. occidentalis. Black R. or thimble-berry. . . . . A

R. villosus. High blackberry. . . *A

R. Canadensis. Low blackberry. . *A

R. hispidus. Swamp blackberry.

Rosa Carolina. . . . . A

R. lucida. Wild roses. . . . A

R. blanda.

R. rubiginosa. Sweet-brier.

Cratægus Oxyacantha.
Claremont.

C. coccinea. . . . . *

C. tomentosa; var. pyrifolia. Thorn.
var. punctata.

C. Crus-Galli.

Pyrus arbutifolia. Choke-berry. . *

P. Americana. Mountain-ash. . **C*; †M

Amelanchier Canadensis;
var. Botryapium. } Shad-bush, or Service-berry. *
var. oblongifolia. *
var. oligocarpa.

SAXIFRAGE FAMILY.

Ribes Cynosbati. } Wild gooseberry. . . . . . *
R. hirtellum. *
R. lacustre. . . . . *C*; †M

R. prostratum. Skunk currant. *C*; †M

R. floridum. Wild black currant.

R. rubrum. Wild red currant. . . *C*

Saxifraga rivularis. . . . . . *M*

S. Virginiensis. Saxifrage. . . C

S. Pennsylvanica.

Mitella diphylla. Mitre-wort.

Tiarella cordifolia. False mitre-wort. *

Chrysosplenium Americanum.

ORPINE FAMILY.

Penthorum sedoides. Ditch Stone-crop. *

Sedum Telephium.
Orpine, or Live-forever.

WITCH-HAZEL FAMILY.

Hamamelis Virginica. Witch-Hazel. *

WATER-MILFOIL FAMILY.

Myriophyllum tenellum. Water Milfoil.

EVENING-PRIMROSE FAMILY.

Circæa Lutetiana. Enchanter's Night-shade. . . . . . . *

C. alpina. . . . . *

Epilobium angustifolium. . . . . *

E. alpinum, and var. majus. . . *M*

E. palustre; var. lineare. Willow-herb.

E. molle.

E. coloratum. . . . . . . *

Œnothera biennis. . . . . . *
var. cruciata.
Charlestown.

Œ. pumila. Evening-Primrose. . *

Ludwigia palustris. Water Purslane.

MELASTOMA FAMILY.

Rhexia Virginica. Deer-Grass. . *A*

LOOSESTRIFE FAMILY.

Lythrum Salicaria.

Nesæa verticillata. Swamp Loosestrife.

GOURD FAMILY.

Sicyos angulatus. One-seeded Star-cucumber. . . . . . . *A*

Echinocystis lobata. Wild Balsam-apple. (Indigenous westward.)

PARSLEY FAMILY.

Hydrocotyle Americana.

Sanicula Marilandica. Black Snakeroot.*

S. Canadensis.

Daucus Carota. Carrot.

Carum Carui. Caraway.

Heracleum lanatum. . . . . *C; †M
{Cow Parsnip. "Masterwort."}

Pastinaca sativa. Parsnip.

Archangelica atropurpurea. Angelica. C

A. Gmelini. . . . . . . *S*

Conioselinum Canadense. Hemlock-Parsley. C

Ligusticum Scoticum. Scotch Lovage. *S*

Thaspium aureum. Meadow Parsnip. *

Cicuta maculata. Water-Hemlock, or *
C. bulbifera. Beaver Poison.

Sium lineare. Water Parsnip. . . *

Cryptotænia Canadensis. Honewort.

Osmorrhiza longistylis.

O. brevistylis. Sweet Cicely.

Conium maculatum. Poison Hemlock. Claremont.

GINSENG FAMILY.

Aralia racemosa. Spikenard.

A. hispida. Wild Elder. *

A. nudicaulis. Sarsaparilla. . . *

A. quinquefolia.

A. trifolia. Dwarf Ginseng. . . *

DOGWOOD FAMILY.

Cornus Canadensis. Bunch-berry. *; †M

C. florida. Flowering Dogwood.

C. circinata.

C. sericea.

C. stolonifera. Dogwood, or Cornel. *

C. paniculata.

C. alternifolia. . . . . . . *

Nyssa multiflora. Sour-Gum Tree.

HONEYSUCKLE FAMILY.

Linnæa borealis. Twin-flower. *C; †M

Symphoricarpus racemosus. Snowberry. (Indigenous westward.)

Lonicera grata. Woodbine. (Indigenous westward.)

L. ciliata.

L. cærulea. Fly-honeysuckle. . *C; †M*

Diervilla trifida. Bush-honeysuckle. . *

Sambucus Canadensis. Common elder. *

S. pubens. Red-berried elder. . . C

Viburnum Lentago. Sweet viburnum.

V. nudum. Withe-rod.

V. dentatum. Arrow-wood.

V. acerifolium. Dockmackie.

V. pauciflorum. . . . . . *C; †M*

V. opulus. Cranberry-tree. . . **C*

V. lantanoides. Hobblebush. . . *

MADDER FAMILY.

Galium asprellum. . . . . . *

G. trifidum. Bedstraw, or Cleavers. . . *

G. triflorum. . . . . . . *

G. circæzans. Wild liquorice.

G. lanceolatum.

Cephalanthus occidentalis. Button-bush. . . . . *A

Mitchella repens. {Partridge-berry. "Fox-berry."} . . *

Houstonia cærulea. Bluets. . *; †M

COMPOSITE FAMILY.

Liatris scariosa. Blazing star. . . *A*

Eupatorium purpureum. Joe-Pye Weed. *

E. perfoliatum. Thoroughwort. . *

E. ageratoides. White snakeroot. . *C

Nardosmia palmata. Sweet coltsfoot.

Tussilago Farfara. Coltsfoot.

Sericocarpus conyzoides.
White-topped aster. *

Aster corymbosus. . . . . . *
A. macrophyllus. . . . . . *
A. Radula. . . . . . †M
A. patens.
A. lævis and var. cyaneus.
A. lævis; var. cyaneus. . . . . *
A. undulatus. . . . . . . *
A. cordifolius. Aster, or Starwort. . *
A. multiflorus. "Frostweed."
A. dumosus.
A. Tradescanti.
A. miser. . . . . *
A. simplex.
A. longifolius.
A. puniceus. . . . . . . *
A. acuminatus. . . . . . * †M
A. nemoralis. . . . . . . †M
A. flexuosus. . . . . . . *S*
A. linifolius. . . . . . . *S*

Erigeron Canadense. Horse-weed. . *
E. bellidifolium. Robin's Plantain. . *
E. Philadelphicum.
E. annuum. Fleabane. . . . *
E. strigosum. . . . . . . *

Diplopappus linariifolius. . . . *
D. umbellatus. Double-bristled aster. *

Solidago squarrosa.
S. bicolor.
S. latifolia. . . . . . . *C*
S. cæisa.
S. puberula. . . . . . . S
S. Virga-aurea;
var. alpina. . . *M*
var. humilis.
S. thyrsoidea. . . . . *C*; †M

S. sempervirens. . . . . . *S*
S. neglecta. Golden-rod.
S. arguta; var. juncea. . . . *A
S. Muhlenbergii.
S. altissima. . . . . . . *
S. odora. Sweet golden-rod. . . A
S. nemoralis.
S. Canadensis.
S. serotina.
S. gigantea.
S. lanceolata. . . . . . *
S. tenuifolia. . . . . . . S
North Conway.

Inula Helenium. Elecampane.

Ambrosia artemisiæfolia.
Roman wormwood. . . *
Xanthium strumarium.
Heliopsis lævis.
Rudbeckia laciniata.
R. hirta. Cone-flower.
(Introduced from western United States.)

Helianthus annuus.
H. strumosus.
H. divaricatus. Sunflower.
H. decapetalus.
H. tuberosus. Artichoke.

Bidens frondosa. . . . . . *
B. connata.
B. cernua. Beggar-ticks. Bur-Marigold. . . *
B. crysanthemoides.
B. Beckii.

Maruta Cotula. May-weed.
Achillea Millefolium. { Yarrow. Milfoil. . *
Leucanthemum vulgare. { Ox-eye daisy. White-weed. *
Tanacetum vulgare. Tansy.
Artemisia Absinthium. Garden Wormwood.
A. Canadensis.

*Artemisia caudata.
Gnaphalium decurrens.
G. polycephalum.
G. uliginosum. Cudweed. . . *
G. purpureum. . . . . . . *S*
G. supinum. . . . . . . *M*

Antennaria margaritacea. Everlasting. *; †M
A. plantaginifolia. . . . . . *

Erechthites hieracifolia. Fireweed. . *

Senecio aureus. Golden Ragwort.

Arnica mollis. . . . . . . *M*

Cirsium lanceolatum. Thistle.
C. discolor.
C. muticum. C
C. pumilum. Pasture Thistle. . . *A
C. arvense. Canada Thistle. . . *

Lappa officinalis. Burdock.

Cichorium Intybus. Succory.

Krigia Virginica. Dwarf Dandelion.

Leontodon autumnale. Fall Dandelion. A

Hieracium Canadense. Hawkweed.
H. scabrum. . . . . . . *
H. Gronovii. Claremont.
H. venosum. Rattlesnake-weed. . . *
H. paniculatum.

Nabalus albus. . . . . . . *
N. altissimus. Rattlesnake-root.
N. nanus. . . . . *M*
N. Bootii. . . . . *M*

Taraxacum Dens-leonis. Dandelion. *; †M

Lactuca Canadensis. / do., var. sanguinea. } Wild Lettuce. *

Mulgedium leucophæum. Blue Lettuce.

Sonchus oleraceus.
S. asper. Sow-Thistle.

LOBELIA FAMILY.

Lobelia cardinalis. Cardinal-flower. *A
L. inflata. Indian Tobacco, or Lobelia. *
L. spicata.
L. Kalmii.
L. Dortmanna. Water Lobelia.

CAMPANULA FAMILY.

Campanula rotundifolia. Harebell. *; †M
C. aparinoides. Marsh Bellflower.
Specularia perfoliata.

HEATH FAMILY.

Gaylussacia resinosa. Huckleberry. *A
G. frondosa.

Vaccinium Oxycoccus. Small cranberry. . . . . . *C*; †M
V. macrocarpon. Common cranberry. *A
V. Vitis-Idæa. Cowberry. . . *M*
V. uliginosum. Bog Bilberry. . . *M*
V. cæspitosum. . . . . . . *M*
V. Pennsylvanicum. Low Blueberry. *; †M
V. Canadense. . . . . . . *C*
V. vacillans. . . . . . . *A*
V. corymbosum. High Blueberry. . *A

Chiogenes hispidula. Creeping Snowberry. . . . . . . C; †M

Arctostaphylos Uva-ursi.
A. alpina. Bearberry. . . . *M*
Epigæa repens. Mayflower. . . *

Gaultheria procumbens. Checkerberry. *

Cassandra calyculata. Leather-leaf. . *

Cassiope hypnoides. . . . . . *M*

Andromeda polifolia.
A. ligustrina. . . . . . . *

Clethra alnifolia. White alder. . . *A*

Phyllodoce taxifolia. . . . . . *M*

Kalmia latifolia. { Spoonwood. / Mountain-laurel. } . **A*

* *Gray's Manual*, 1870.

K. angustifolia. Lambkill. . . *A

K. glauca. Pale laurel. . . C; †M

Azalea nudiflora. "Election Pink." . *A*

Rhododendron maximum.
Great Rose-bay. *A*
Richmond, Grantham, Fitzwilliam.

R. Lapponicum. Lapland Rose-bay. *M*

Rhodora Canadensis. . . . . *

Ledum latifolium. Labrador tea. *C;* †M

Loiseleuria procumbens.
Alpine Azalea. *M*

Pyrola rotundifolia.

P. elliptica.

P. chlorantha. Wintergreen.

P. secunda. . . . . . . *

P. minor. C

Moneses uniflora.

Chimaphila umbellata. { Prince's Pine. Pipsissewa. } *

Monotropa uniflora. { Indian pipe. Corpse plant. } . *

M. Hypopitys. Pine sap.

HOLLY FAMILY.

Ilex verticillata. Black Alder. . . *A

I. laevigata. Winterberry. . . A

Nemopanthes Canadensis.
Mountain holly. *

PLANTAIN FAMILY.

Plantago major. Plantain. . . *

P. maritima; var. juncoides. . . *S*

P. lanceolata. Ribgrass.

LEADWORT FAMILY.

Statice Limonium;
var. Caroliniana. Marsh-rosemary. *S*

PRIMROSE FAMILY.

Trientalis Americana. Star-flower. *; †M

Lysimachia thyrsiflora. *

L. stricta. . . . . *

L. quadrifolia. Loosestrife. . . *

L. ciliata.

L. lanceolata.

Glaux maritima. Sea-milkwort. . *S*

Anagallis arvensis.

BLADDERWORT FAMILY.

Utricularia inflata.

U. vulgaris. Bladderwort.

U. minor.
U. intermedia.
U. gibba. } Claremont.

U. cornuta.

BROOM-RAPE FAMILY.

Epiphegus Virginiana. Beech-drops. *C*

FIGWORT FAMILY.

Verbascum Thapsus. Common mullein. *

V. Blattaria. Moth mullein.

Linaria Canadensis. Wild Toad-flax. *

L. vulgaris. Butter-and-eggs.

Chelone glabra. Snake-head. . . *

Mimulus ringens. Monkey-flower. . *

Gratiola aurea. Hedge-hyssop.

Ilysanthes gratioloides. False Pimpernel.

Veronica Anagallis.

V. Americana.

V. scutellata. . . . . *

V. officinalis. Speedwell.

V. alpina. . . . . *M*

V. serpyllifolia. . . . . . . *

V. arvensis.

Gerardia tenuifolia. Gerardia.

G. quercifolia. Foxglove.

G. pedicularia.

Castilleia pallida. Painted-cup. . *M*

Schwalbea Americana. . . . A
Walpole plains! rare.

Euphrasia officinalis. Eyebright. . *M*

Rhinanthus Crista-galli. Yellow Rattle. *M*

Pedicularis Canadensis. . . . *

P. lanceolata. Lousewort. . . *A*

Melampyrum Americanum. Cow-wheat. *; †M

VERVAIN FAMILY.

Verbena hastata. Blue vervain. . *A

V. urticifolia. White vervain. . . A

Phryma Leptostachya. Claremont.

MINT FAMILY.

Teucrium Canadense. Wood Sage.

Trichostema dichotomum. False Pennyroyal. . . . . . *A*

Mentha viridis. Spearmint.

M. piperita. Peppermint.

M. sativa.

M. Canadensis. Wild mint. . . *

Lycopus Virginicus. Water Horehound. *

L. Europæus.
do. var. sinuatus. . . . *

Pycnanthemum incanum. Claremont.

P. lanceolatum. Mountain Mint.

Origanum vulgare. Wild Marjoram.

Calamintha Clinopodium. Basil.

Hedeoma pulegioides. American Pennyroyal. . . . . . *A

Monarda didyma. { Oswego Tea. Balm. }

M. punctata. Horse-mint.

Lophanthus nepetoides.

L. scrophulariæfolius. Giant Hyssop.

Nepeta Cataria. Catnip.

N. Glechoma. Gill.

Brunella vulgaris. Self-heal. . . *

Scutellaria galericulata.

S. lateriflora. Skullcap. . . . *

Marrubium vulgare. Horehound.

Galeopsis Tetrahit. Hemp-Nettle. . *

Stachys palustris; var. aspera.

Leonurus Cardiaca. Motherwort. *

Lamium amplexicaule. Dead-nettle.

BORRAGE FAMILY.

Symphytum officinale. Comfrey.

Lithospermum officinale. Gromwell.

Myosotis palustris; var. laxa. Forget-me-not.

Echinospermum Lappula.

Cynoglossum officinale. Hound's-tongue.

C. Morisoni.

WATERLEAF FAMILY.

Hydrophyllum Virginicum. Waterleaf.

POLEMONIUM FAMILY.

Diapensia Lapponica. . . . **M*

CONVOLVULUS FAMILY.

Calystegia sepium. . . . . A

C. spithamæa. Bracted Bindweed. . A

Cuscuta Epilinum.

C. Gronovii. Dodder. . . . *

NIGHTSHADE FAMILY.

Solanum Dulcamara. Bittersweet.

S. nigrum. Nightshade.

Physalis viscosa. Ground Cherry.

Nicandra physaloides. Apple of Peru.

Hyoscyamus niger. Henbane.

Datura Stramonium. Thorn-apple.

GENTIAN FAMILY.

Gentiana crinita. Fringed Gentian.

G. Andrewsii. Closed Gentian.

G. Saponaria; var. linearis.

Menyanthes trifoliata. Buckbean.

Limnanthemum lacunosum. Floating Heart.

DOGBANE FAMILY.

Apocynum androsæmifolium. Dogbane. *

A. cannabinum. Indian Hemp.

MILKWEED FAMILY.

Asclepias Cornuti. Milkweed. . . *

A. phytolaccoides. . . . . *

A. purpurascens.

A. incarnata.
A. quadrifolia.
A. obtusifolia.
A. tuberosa. Pleurisy-root.
A. verticillata.

OLIVE FAMILY.

Ligustrum vulgare. Privet.

Fraxinus Americana. White Ash. . *
F. pubescens. Red Ash.
F. sambucifolia. Black Ash. . . *

BIRTHWORT FAMILY.

Asarum Canadense. Wild ginger. . *C*

Aristolochia Serpentaria. . . . *A*
Virginia Snakeroot.

POKEWEED FAMILY.

Phytolacca decandra. Garget. Poke. A

GOOSEFOOT FAMILY.

Chenopodium album. Pigweed. . *
C. polyspermum.
C. hybridum.
C. urbicum.
C. Botrys. Jerusalem oak.
C. ambrosioides; var. *anthelminticum.*

Roubieva multifida.
Claremont.

Atriplex patula. S
Salicornia herbacea. . . . . *S*
S. Virginica. Samphire. . . . *S*
Suæda maritima. Sea Blite. . . *S*
Salsola Kali. Saltwort. . . . *S*

AMARANTH FAMILY.

Amarantus retroflexus. Pigweed. . *
do. *var. hybridus.*

A. albus.

BUCKWHEAT FAMILY.

Polygonum viviparum. Alpine Bistort. *M*
P. orientale. Prince's Feather.
P. Careyi.
P. Pennsylvanicum.
P. incarnatum.
P. lapathifolium.
P. Persicaria. { *Lady's thumb. Heartweed.* } . *
P. Hydropiper. Smartweed. . . *
P. acre.
P. hydropiperoides.
P. amphibium. Water Persicaria.
P. Virginianum.
P. articulatum. Jointweed. . . S
Nashua, Manchester, and Concord.
P. aviculare. Knotgrass. Doorweed. *
do. var. erectum.
P. arifolium. { Tear-thumb.
P. sagittatum. } . . . . . *
P. convolvulus. Black Bindweed. . *
P. cilinode.
P. dumetorum;
var. scandens. { Climbing false buckwheat. }

Fagopyrum esculentum. Buckwheat.

Oxyria digyna. Mountain sorrel. . *M*

Rumex orbiculatus. Great Water-dock.
R. verticillatus.
R. altissimus. (Wood.)
Claremont.

R. crispus. Common Dock. . . *
R. obtusifolius.
R. sanguineus. Bloody-veined Dock.
R. Patientia. Patience Dock.
R. Acetosella. Field sorrel. . *; †M

LAUREL FAMILY.

Sassafras officinale. Sassafras. . *A

Lindera Benzoin. Spice-bush.

MEZEREUM FAMILY.

Dirca palustris. Moosewood. Wicopy. *C*

SANDALWOOD FAMILY.

Comandra umbellata.
Bastard Toad-flax. A

HORNWORT FAMILY.

Ceratophyllum demersum. Hornwort.

WATER-STARWORT FAMILY.

Callitriche verna. Water-starwort. *

C. terrestris.

SPURGE FAMILY.

Euphorbia polygonifolia. . . . *S*

E. maculata.

E. hypericifolia. Spurge.

E. Esula.

E. Cyparissias.

Acalypha Virginica.
Three-seeded Mercury.

CROWBERRY FAMILY.

Empetrum nigrum. Crowberry. . *M*

NETTLE FAMILY.

Ulmus fulva. Slippery elm.

U. Americana. White elm. . . *

U. racemosa.
Walpole, Hanover.

Celtis occidentalis. Sugarberry.
Claremont, Walpole.

Morus alba. Mulberry.

Urtica gracilis.

U. dioica. Nettle.

U. urens.

Laportea Canadensis. Wood-nettle.

Pilea pumila. Richweed.

Bœhmeria cylindrica. False Nettle.

Cannabis sativa. Hemp.

Humulus Lupulus. Hop.

PLANE-TREE FAMILY.

Platanus occidentalis. Buttonwood. *A*

WALNUT FAMILY.

Juglans cinerea. { Butternut. Oilnut.

Carya alba. Shell-bark Hickory. . **A*

C. tomentosa. Pig-nut. . . . **A*

C. porcina. . . . . . . *A*
Claremont.

C. amara. . . . . *A*

OAK FAMILY.

Quercus alba. White oak. . . **A*

Q. obtusiloba. Post-oak. . . . *A*

Q. Prinus. Chestnut oak. . . . *A*
Amherst, West Ossipee.

Q. nigra. . . . . *A*

Q. ilicifolia. Scrub-oak. . . . **A*

Q. coccinea; var. tinctoria. Black oak. *A*

Q. rubra. Red oak. . . . . *A

Castanea vesca. Chestnut. . . **A*

Fagus ferruginea. Beech. . . . *C

Corylus Americana. . . . . *

C. rostrata. Hazel-nut. . . . *

Ostrya Virginica. Lever-wood.

Carpinus Americana. { Iron-wood. Hornbeam.

SWEET-GALE FAMILY.

Myrica Gale. Sweet Gale. . . *

M. cerifera. Bayberry. . . . S
Milford, New Boston.

Comptonia asplenifolia. Sweet Fern. *A

BIRCH FAMILY.

Betula lenta. Sweet, or Black Birch.

B. lutea. Silver, or Yellow Birch. . *

B. alba; var. populifolia. White Birch.**A*

B. papyracea.
Canoe, or Paper Birch. *; †M

B. nigra.
Atkinson, Acworth.

B. pumila. Low Birch.

B. glandulosa. Dwarf Birch. . . *M*

Alnus viridis. Mountain Alder. *C*; †M

A. incana. Common Alder. . . *

A. serrulata. . . . . . . *A*

WILLOW FAMILY.

Salix candida. . . . . . . *C*

S. humilis.

S. discolor. . . . . *

S. sericea.

S. viminalis.
Rollinsford.

S. cordata. . . . . *

S. livida; var. occidentalis. . . *
S. chlorophylla. Willows. . . *M*
S. lucida.
S. nigra.
S. fragilis.
S. alba. . . . . *
S. Babylonica.
S. Cutleri. . . . . *M*
S. argyrocarpa. . . . . . *M*
S. herbacea. . . . . . . *M*

Populus tremuloides. Poplar, or Aspen.*
P. grandidentata. . . . . *
P. heterophylla.
P. monilifera. Cottonwood.
P. balsamifera; & var. candicans. Balm of Gilead. *C*
P. dilatata. Lombardy Poplar.

PINE FAMILY.

Pinus rigida. Pitch Pine. . . . **A*
P. resinosa. { Red Pine. "Norway Pine." } . A
P. Strobus. White Pine. . . . *A

Abies nigra. Black Spruce. . *C; †M
A. alba. White Spruce. . . . **C*
A. Canadensis. Hemlock. . . *A
A. balsamea. Balsam Fir. . *C; †M

Larix Americana. { American Larch. Hackmatack. }

Thuja occidentalis. { Arbor-vitæ. "White Cedar." } **C*
Sutton, Alstead.

Juniperus communis. Juniper. . . A

J. Virginiana. { Red cedar. Savin. } . . A

Taxus baccata; var. Canadensis. Ground Hemlock. *

ARUM FAMILY.

Arisaema triphyllum. Indian turnip. *
A. Dracontium.
Claremont.

Calla palustris. { Water Arum. Wild Calla-lily. } . *C
Symplocarpus fœtidus. Skunk cabbage.
Acorus Calamus. Sweet flag.

CAT-TAIL FAMILY.

Typha latifolia. Cat-tail flag. . . *
Sparganium eurycarpum. Bur-reed.
S. simplex; var. fluitans.
var. angustifolium.

PONDWEED FAMILY.

Naias flexilis.
Zannichellia palustris.
Claremont.
Zostera marina. Eel-grass. . . *S*
Ruppia maritima. Ditch-grass. . *S*
Potamogeton natans. . . . . *
P. Claytonii.
P. Spirillus.
P. hybridus.
P. amplifolius. Pondweed.
P. gramineus.
P. lucens.
P. perfoliatus.
P. pauciflorus.
P. pusillus.
P. Robbinsii.
* P. Tuckermani. { C
Claremont! }

WATER-PLANTAIN FAMILY.

Triglochin maritimum. Arrow-grass. *S*
Scheuchzeria palustris.
Alisma Plantago; var. Americanum. Water plantain.
Sagittaria variabilis. . . . . . *
S. graminea. Arrow-head.

FROG'S-BIT FAMILY.

Vallisneria spiralis.

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* *Gray's Manual*, 1870.

ORCHIS FAMILY.

Orchis spectabilis.
Habenaria tridentata. . . . *C*
H. virescens. . . . . . .
H. viridis; var. bracteata. . . *C*
H. hyperborea. . . . . . . *C*
H. dilatata. . . . . *C*; †M
H. obtusata. Orchis. . . . †M
H. Hookeri.
H. orbiculata. C
H. ciliaris.
Langdon.
H. blephariglottis.
H. lacera.
H. psycodes. Purple fringed-orchis. *
H. fimbriata.

Goodyera repens. Rattlesnake-plantain.
G. pubescens.

Spiranthes cernua. . . . . . *
S. gracilis. Ladies' tresses.

Listera cordata. Twayblade. . . †M

Arethusa bulbosa.

Pogonia ophioglossoides. *

Calopogon pulchellus.

Calypso borealis.

Microstylis monophyllos. . . . C
M. ophioglossoides. Adder's-mouth.

Liparis Lœselii. Twayblade.

Corallorhiza innata. . . . . . A
C. multiflora. Coral-root.
C. odontorhiza.

Aplectrum hyemale.

Cypripedium acaule. Lady's slipper. *
C. arietinum.
Walpole.
C. pubescens.
C. spectabile.
Lebanon.

AMARYLLIS FAMILY.

Hypoxys erecta. Star-grass.
Alstead.

IRIS FAMILY.

Iris versicolor. Blue flag. Iris. . *

Sisyrinchium Bermudiana.
Blue-eyed grass. *

SMILAX FAMILY.

Smilax rotundifolia. Greenbrier. . **A*
S. herbacea. Carrion flower. . . *
do. var. pulverulenta.

LILY FAMILY.

Trillium erectum. Purple Trillium. . *
T. cernuum. Wake-robin.
T. erythrocarpum. Painted Trillium. *
do. var. Clevelandicum.
Claremont.

Medeola Virginica.
Indian Cucumber-root. *

Veratrum viride. Indian Poke. *; †M

Uvularia perfoliata.
U. sessilifolia. Bellwort. . . . *
U. grandiflora.
Claremont.

Streptopus amplexifolius. . . C; †M
S. roseus. Twisted-stalk. . . C; †M
Convallaria majalis.

Clintonia borealis. Clintonia. . *; †M
C. umbellata.
Claremont.

Smilacina racemosa. . . . . *
S. stellata.
S. trifolia. False Solomon's Seal.
S. bifolia. . . . . *

Polygonatum biflorum. . . . *
P. giganteum. Solomon's Seal.

Asparagus officinalis. *Asparagus*.

Lilium Philadelphicum. . . . *
L. Canadense. Lily. . . . *
L. superbum.

Erythronium Americanum. Adder's-tongue. *

Allium tricoccum. Wild Leek.
Campton, Colebrook, Hanover.

A. Canadense.

A. Schœnoprasum. Chives.
(Indigenous in north-western U. S.)

Hemerocallis fulva. Day-lily.

RUSH FAMILY.

Luzula pilosa.

L. parviflora; var. melanocarpa. . †M

L. campestris. Wood-rush.

L. arcuata. . . . . . . *M*

L. spicata. . . . . *M*

Juncus effusus. . . . . . . *

J. filiformis, ... †M

J. scirpoides.

J. Balticus. . . . . . . *S*

J. trifidus. . . . . *M*

J. marginatus.

J. bufonius. . . . . . . *

J. Gerardi. . . . . . . *S*

J. tenuis. Rush. Bog-rush. . . *

J. Greenii. . . . . . . S
Concord, Gilmanton.

J. pelocarpus.

J. acuminatus.

J. nodosus.

J. Canadensis; var. coarctatus.
do. var. longicaudatus.

PICKEREL-WEED FAMILY.

Pontederia cordata. Pickerel-weed. . *

YELLOW-EYED GRASS FAMILY.

Xyris flexuosa. Yellow-eyed Grass.
do. var. pusilla.

PIPEWORT FAMILY.

Eriocaulon septangulare. Pipewort.

SEDGE FAMILY.

Cyperus diandrus. . . . . . *

C. dentatus. Sedge.

C. strigosus. . . . . . . *

C. inflexus.

C. filiculmis. Nut-grass. . . . . *

C. phymatodes.

Dulichium spathaceum. . . . . *

Eleocharis Robbinsii.

E. obtusa. . . . . *

E. palustris. Spike-rush.

E. tenuis. . . . . *

E. acicularis. . . . . *

Scirpus cæspitosus. . . . . . *M*

S. subterminalis.

S. pungens.

S. Torreyi.

S. validus. . . . . *

S. debilis. Bulrush. Club-rush.

S. maritimus. . . . . *S*

S. sylvaticus. . . . . *

S. microcarpus.

S. atrovirens.

S. Eriophorum. Wool-grass. . . *

Eriophorum alpinum.

E. vaginatum. . . . . . . †M

E. Virginicum. Cotton-grass. . . *

E. polystachyon. . . . . . *

E. gracile.

Fimbristylis autumnalis.

F. capillaris. . . . . *

Rhynchospora alba. . . . . . *

R. glomerata. Beak-rush.

R. fusca.
Plainfield.

Cladium mariscoides. Twig-rush. . *

Carex scirpoidea. . . . . . *M*

C. capitata. . . . . . . *M*

C. pauciflora.

C. polytrichoides. . . . . . *

C. Backii.
Gilmanton.

C. vulpinoidea. . . . . *

C. stipata. . . . . *

C. sparganioides.

C. cephalophora.

C. rosea; . . . . *
do. var. radiata.

C. tenella.

C. trisperma. . . . . . *; †M

C. canescens; . . . . . *; †M
do. var. vitilis.

C. Deweyana. . . . . . . *

C. sterilis.

C. stellulata; . . . . . *
do. var. scirpoides. . . *

C. scoparia. . . . . . . *

C. lagopodioides. . . . . *

C. cristata;
do. var. mirabilis.

C. straminea; . . . . . . *
do. var. typica.
do. var. tenera.
do. var. aperta.
do. var. festucacea.

C. rigida; var. Bigelovii. . . . . *M*

C. vulgaris. . . . . . . *

C. aperta.

C. stricta; . . . . *
do. var. strictior.

C. aquatilis.

C. lenticularis.

C. torta.

C. crinita. . . . . *

C. gynandra. . . . . . . *

C. limosa. . . . . . . †M

C. irrigua.

C. atrata. . . . . *M*

C. aurea.

C. granularis. . . . . . . *

C. pallescens. . . . . . . *

C. conoidea. . . . . . . *

C. formosa.

C. gracillima. . . . . . . *

C. virescens.

C. plantaginea.

C. platyphylla.

C. digitalis.

C. laxiflora; . . . . *
do. plantaginea.
do. var. blanda.

C. pedunculata.

C. umbellata. . . . . . . *

C. Novæ-Angliæ.

C. Pennsylvanica. . . . . . *

C. varia. . . . . *

C. pubescens. . . . . . . *

C. miliacea.

C. scabrata. . . . . . . *

C. arctata. . . . . . . *; †M

C. debilis. . . . . *

C. capillaris. . . . . . . *M*

C. flava. . . . . *

C. filiformis.

C. riparia.

C. comosa.

C. Pseudo-Cyperus.

C. hystricina; . . . . . . *
do. var. Cooleyi.

C. tentaculata. . . . . . . *

C. intumescens. . . . . . . *

C. folliculata.

C. lupulina. . . . . . *

C. subulata.

C. rostrata. . . . . . . †M

C. utriculata.

C. monile. . . . . *

C. Tuckermani.

C. bullata.

C. oligosperma.

GRASS FAMILY.

Leersia Virginica.

L. oryzoides. Rice cut-grass. . . *

Zizania aquatica. Water oats. . . *C*
Androscoggin river.

Alopecurus pratensis.

A. geniculatus.

Phleum pratense. Herds Grass. *; †M

P. alpinum. . . . . . . *M*

Vilfa vaginæflora.

Sporobolus serotinus. Drop-seed Grass. *

Agrostis perennans. Thin-grass.
A. scabra. Hair-grass. . . *; †M
A. canina; . . . . †M
do. var. alpina.
A. vulgaris. Red-top. . . . *
A. alba.

Polypogon Monspeliensis. . . . *S*

Cinna arundinacea;
do. var. pendula.

Muhlenbergia glomerata.
M. Mexicana.
M. sylvatica.

Brachyelytrum aristatum.

Calamagrostis Canadensis. Blue-Joint Grass. *
C. Langsdorffii. . . . . . *M*
C. Pickeringii. . . . . . . M
C. arenaria. Sea Sand-Reed. . . *S*

Oryzopsis melanocarpa.

O. asperifolia. . . . . . . *
O. Canadensis.

Spartina juncea. . . . . . . *S*
S. stricta; Salt Marsh-Grass. . . *S*
var. glabra.
var. alterniflora.

Eleusine Indica.

Dactylis glomerata. Orchard Grass.

Glyceria Canadensis. . . . . . *
G. elongata.
G. nervata. Manna-Grass. . . *
G. pallida.
G. aquatica. . . . . . . *
G. fluitans. . . . . . . *
G. acutiflora.
G. maritima. Sea Spear-Grass. . *S*

Brizopyrum spicatum. Spike-Grass. . *S*

Poa annua. Low Spear-Grass.
P. compressa. Wire-Grass. . . *
P. laxa. . . . . *M*
P. serotina. False Red-top.
P. pratensis. { Common Spear-Grass. June Grass. } *
P. alsodes.
P. trivialis.

Eragrostis pectinacea.

Briza media.

Festuca tenella.
F. ovina. Fescue Grass.
F. elatior. . . . . *
F. nutans.

Bromus secalinus. Chess.
B. ciliatus. "Wild Oats." . . *

Triticum repens. "Witch-Grass." . *
T. violaceum. . . . . . . *M*

Elymus Virginicus.
E. Canadensis. Wild Rye.
E. striatus.
E. mollis.

Gymnostichum Hystrix.

Danthonia spicata. "White-top Grass." *

Avena striata. . . . . *C*; †M

Trisetum subspicatum; var. molle. C; †M

Aira flexuosa. Hair-Grass. . . †M
A. atropurpurea. . . . . **M*

Hierochloa alpina. . . . . *M*

Anthoxanthum odoratum. Sweet Vernal Grass.

Phalaris Canariensis. Canary Grass.
P. arundinacea. Reed Canary-Grass. *C*

Paspalum setaceum. . . . . *A*

Panicum glabrum.

P. sanguinale. { *Crab-Grass. Finger-Grass*. } . . *
P. agrostoides.
P. capillare. . . . . . . *

P. latifolium. . . . . . . *
P. clandestinum. Panic-Grass.
P. xanthophysum.
P. dichotomum. . . . . . . *
P. depauperatum.
P. Crus-galli. Barnyard-Grass. . *

Setaria glauca. . . . . . . *
S. viridis. Bristly Foxtail-Grass. . *
S. verticillata.

Cenchrus tribuloides. Bur-Grass. . A

Andropogon furcatus. . . . *
A. scoparius. Beard-Grass. . . *
A. Virginicus.

HORSETAIL FAMILY.

Equisetum arvense. Horsetail. . . *
E. sylvaticum. . . . . . .
E. limosum. *
E. hyemale. Scouring-Rush. . . *
E. variegatum.
Walpole.

FERN FAMILY.

Polypodium vulgare. Polypody. . *

Adiantum pedatum. Maiden-hair.

Pteris aquilina. Brake. Bracken. . *

Woodwardia Virginica. Chain-Fern.
Concord.

Asplenium Trichomanes.
A. ebeneum.
A. angustifolium.
A. thelypteroides. Spleenwort.
A. Filix-fœmina. . . . . . *
do. var. molle.
Bethlehem.

Camptosorus rhizophyllus. Walking-Leaf.
Lebanon.

Phegopteris polypodioides. . . *C
P. hexagonoptera. Beech-Ferns.
P. Dryopteris. . . . . . *C

Aspidium Thelypteris. . . . *
A. Noveboracense. . . . . *
A. fragrans.
Berlin Falls, Gorham.

A. spinulosum. Shield-Ferns.
var. intermedium. . . . . *
var. dilatatum.
var. Bootii.

A. cristatum. Wood-Ferns.
do. var. Clintonianum.

A. Goldianum.
A. marginale. . . . . . *
A. acrostichoides; . . . . . *
do. var. incisum.
A. aculeatum; var. Braunii. . . *C*

Cystopteris bulbifera. . . . C
C. fragilis. Bladder-Fern.

Struthiopteris Germanica. Ostrich Fern. *

Onoclea sensibilis. Sensitive Fern. *
do. var obtusilobata.
Bethlehem.

Woodsia obtusa.
W. ilvensis.
Hanover.
W. glabella.

Dicksonia punctilobula. . . . *

Lygodium palmatum. Climbing Fern.
Hudson.

Osmunda regalis. { Flowering Fern. / "Buck's-horn." } *
O. Claytoniana. . . . . . . *
O. cinnamomea. Cinnamon-Fern. . *

Botrychium Virginicum.
B. lunarioides; Moonwort.
var. obliquum,
var. dissectum.
B. matricaræfolium.
Bethlehem, Lebanon.
B. simplex.
Richmond.
B. lanceolatum.
Richmond.

Ophioglossum vulgatum. Adder's-Tongue.
Hanover, Langdon, Lebanon, Gilmanton.

CLUB-MOSS FAMILY.

Lycopodium lucidulum. . . . *
L. Selago. . . . . *M*

L. inundatum.

L. annotinum; . . . . . *C*
do. var. pungens.

L. dendroideum. Club-Moss. Trailing Evergreen. *

L. clavatum. . . . . . *

L. complanatum. . . . . *
do. var. Sabinæfolium.

Selaginella selaginoides.

S. rupestris.

Isoetes lacustris.
Lebanon.

Lichens of the White Mountains.

Compiled from *Genera Lichenum*.—1872.

Ramalina calicaris, Tuckerm.

Parmelia aleurites, Ach.
P. ambigua.
P. dendritica, Nyl.

Sticta linita, Ach.

Peltigera canina.

Pannaria granatina, Sommerf.
P., intermed. between P. Petersii and P. nigra.

Omphalaria phyllisca.

Leptogium intricatulum, Nyl.
L. muscicola.

Hydrothyria venosa, Russell.

Lecanora discreta, Tuckerm.

Rinodina Ascociscana, Tuckerm.
R. turfacea, Wahl.

Pertusaria glomerata, Ach.

Stereocaulon nanodes, Tuckerm.

Biatora flexuosa, Fr.
B. viridescens, Schrad.
B. atrorufa, Dicks.
B. uliginosa, Schrad.
B. rivulosa, Ach.
B. cyrtella, Ach.
B. globulosa, Floerk.
B. mixta, Fr.
B. hypnophila, Turn.
B. milliaria, Fr.
B. chlorantha, Tuckerm.
B. porphyrites, Tuckerm.
B. pezizoideum, Ach.

Lecidea arctica, Sommerf.
L. Diapensiæ, Th. Fr.
L. polycarpa, Floerk.
L. aglæa, Sommerf.
L. tenebrosa, Flot.
L. lugubris, Sommerf.
L. caudata, Nyl.
L. morio, Schær.

Buellia pulchella, Schrad. (?)
B. coracina, Th.
B. Schæreri, DeNot.
B. alpicola, Nyl.
B. geographica, Schær.

Xylographa parallela, Fr.

Arthonia cinereo-pruinosa, Schær.
A. lurida, Ach.
A. patellulata, Nyl.
A. diffusa, Nyl.
A. lurido-alba, Nyl.

Sphærophorus globiferus, L.
S. fragilis, L.

Calicium curtum, Turn. & Barr.
C. trachelinum, Ach.
C. roscidum, Floerk.
C. disseminatum, Fr.
C. citrinum, Leight.
C. Curtisii, Tuckerm. (?)

Normandina lætevirens, Turn.

Segestria lectissima, Fr.

Staurothele umbrina, Wahl.

Trypethelium virens, Tuckerm.

Sagedia lactea, Koerb.

Verrucaria margacea, Wahl.

Pyrenula leucoplaca, Wallr.

P. lactea, Mass.

Additional Species from Synopsis of Northern Lichens.—1848.

Evernia jubata, Fr.
E. ochroleuca, Fr.
E. vulpina, Ach.
E. purpuracea, Mann.

Cetraria aculeata, Fr.
C. cucullata, Ach.
C. nivalis, Ach.
C. sepincola, Ach.

Nephroma arcticum, Fr.
N. parile, Ach.

Peltigera malacea, Ach.

Sticta pulmonaria, Ach.

Parmelia Fahlunensis, Ach.
P. stygia, Ach.
P. incurva, Fr.
P. centrifuga, Ach.
P. congruens, Ach.
P. obscura, Fr.
P. sorediata, Tuckerm.
P. rubiginosa, Ach.
P. Hypnorum, Fr.
P. cervina, Sommerf.
P. oculata, Fr.
P. badia, Fr.
P. ventosa, Ach.
P. verrucosa, Ach.

Stereocaulon tomentosum, Fr.
S. corallinum, Fr.
S. paschale, Laur.
S. condensatum, Laur.
S. denudatum, Floerk.
S. nanum, Ach.
S. Fibula, Tuckerm.

Cladonia Papillaria, Hoffm.
C. pyxidata, Fr.
C. gracilis, Fr.
C. fimbriata, Fr.
C. decoticata, Floerk.
C. cenotea, Schær.
C. Despreauxii, Bory MS.
C. amaurocræa, Floerk.
C. Boryi, Tuckerm.
C. bellidiflora, Schær.

Bæomyces roseus, Pers.

Biatora decipiens, Fr.
B. placophylla, Fr.
B. Byssoides, Fr.
B. ichmadophila, Fr.
B. ochrophæa, Tuckerm.

Lecidea vesicularis, Ach.
L. Wahlenbergii, Ach.
L. flavo-virescens, Fr.
L. panæola, Ach.
L. confluens, Schær.
L. melancheima, Tuckerm.
L. sabuletorum, Fr.

Umbilicaria pustulata, Hoffm.
U. polyphylla, Hoffm.
U. proboscidea, DC.
U. hirsuta, Ach.
U. hypoborea, Hoffm.
U. erosa, Hoffm.
U. Muhlenbergii, Ach.

Calicium phæomelanum, Tuckerm.
C. melanophæum, Ach.

Endocarpon fluviatile, DC.

NOTE. There is not an entire agreement respecting the limits of the Canadian and Alleghanian districts, as deduced from the study of the plants and animals, and set forth in Chapters XII and XIII. As there are other facts to be presented, derived from the distribution of the birds, and it may be possible to explore the southern part of Cheshire county with reference to the extension of the Canadian district southerly, before the completion of the first volume, I shall defer the sequel to this subject to a subsequent chapter.—C. H. H.

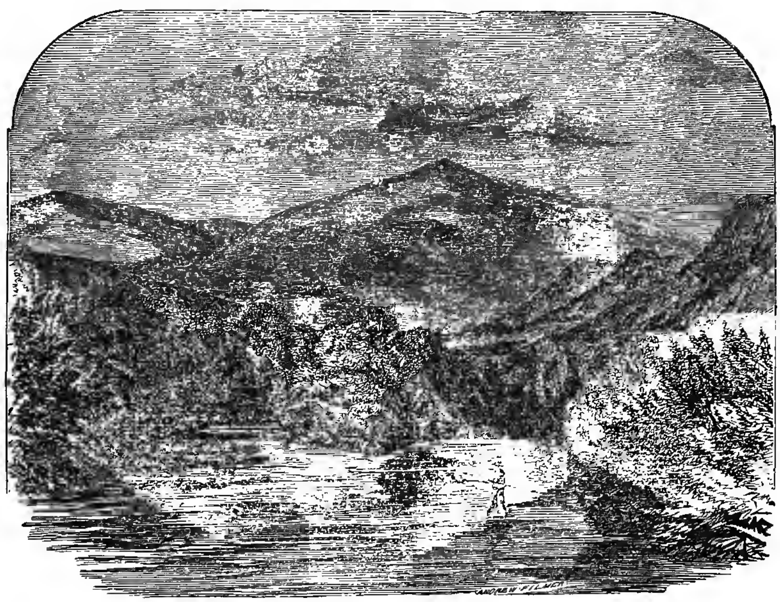


Fig. 60.—MT. MADISON, FROM LEAD MINE BRIDGE, SHELBURNE.

CHAPTER XIV.

NATURAL HISTORY OF THE DIATOMACEÆ.

BY A. MEAD EDWARDS, M. D.

PREFACE.

It is desirable that the reader of the present brief sketch should, at the outset, understand that it is intended to be of an essentially popular character, and by no means a scientific treatise on the diatomaceæ. It has been prepared in such a manner that it will, it is hoped, bring to the attention of others besides strictly scientific observers one of the most beautiful groups of organisms with which the naturalist is acquainted. To that end the language employed is as untechnical as was judged consistent with clearness; and when it has been found necessary to use technical terms, their meaning has been at the same time made plain. This short preface has been intended more specially for the scientist into whose hands this volume may come, so that he may understand its aim and purpose, and, at the same time, not judge it as he would had it made pretence to a position among thoroughly scientific works. At the same time it must be understood that it has of course been made scientifically correct, so that what it teaches concerning the diatomaceæ may be as nearly as possible up to date, and consistent with the latest investigations in this field of research.

INTRODUCTION.

IT is a matter which is well understood at the present day, that if the geologist desires to carry out, in a systematic and scientific manner, his investigations into the history of the globe upon which he dwells, he must earnestly and conscientiously qualify himself for extended and searching observations in many more branches of knowledge than his predecessors of but a few years back considered necessary to the accom-

plishment of their labors. To properly comprehend the structure and modes of formation of strata, be they made up of solid rock or more loosely aggregated material, he must be a mathematician of no low order. To understand the how, the why, and the where of the great stone book laid open to his eye, to read aright the record of the rocks, he must call in to his assistance at least the learning of the physicist, the chemist, and the biologist, if he be not—which, in our present and ever growing state of knowledge is practically impossible—a physicist, a chemist, and a biologist himself. But as it would be evidently impossible for any one man to be thoroughly skilled in all these branches and their various ramifications at one and the same time, the advanced and advancing geologist of to-day carries out the following special plan, when engaged in the study of any tract of country. He secures the coöperation of a number of specialists, persons who have devoted their time and attention more particularly to the study of distinct sections of science, so that the highest skill shall investigate for him the several parts of the work, and thus individual bricks will be contributed to the edifice which the geologist desires to erect. To this end he is aided by at least a chemist, who analyzes for him his rocks, his metallic ores, his marls, or his soils; a zoölogist, who studies the animals found in the section of country gone over; and a botanist, who turns his attention to the plants discovered in the district traversed. If he desires to carry his investigations still further, or if the particular section of country over which his labors extend requires that he should do so, he calls in to his assistance individuals who have turned their attention to particular branches of chemistry, of zoölogy, or of botany. Thus, insects may abound in his field of work, and the farmers will like to know something about the ravages they commit upon the crops; or, vegetable diseases may afflict those crops; or, the rocks may be of a kind made use of in building; or, remarkable kinds of deposits, of great interest to science or of value in the arts, may occur. In all of these, or any similar cases, it will be necessary that the subjects should be investigated by competent observers, and they must be found, and their coöperation secured. Where the geology alone, as restricted by the boundaries which limited it a few years back, is considered, but few of these specialists will be required to assist. But, at the present day, and, more particularly, as is the case

with our state surveys, where the gentleman who accepts the position of state geologist is expected to make his investigations practically applicable and at an early date, the field of labor is very much more extended, and the assistants required much larger in number. Hence it has come to pass that the modern geologist recognizes the necessity of attaching to his staff of assistants one who is specially skilled in the use of the microscope, an instrument, the proper employment of which necessitates a long and severe schooling of the hand and mind, but more particularly the eye in a peculiar manner and direction. For microscopy has become a science in itself, so that, though the naturalist, the chemist, or the physician may possess and look through microscopes, yet it requires one who has mastered its secrets, and has skilled himself in its most advantageous workings, to apply it so as to obtain the best results. But, even in microscopy as a branch of science, there are specialists. Thus, we find one who devotes himself almost exclusively to perfecting the optical portions of the instrument; another will study its application to chemistry and toxicology alone; another, its use in medicine, pathology, and physiology; another, its employment as an adjunct to geology, and so on, as can be readily understood; for science and knowledge are growing so rapidly nowadays that division of labor becomes as necessary therein as it has been found to be in the mechanic arts.

These few words, by way of an introduction, have been deemed necessary, so that the general reader, into whose hands these volumes may come, might understand that the geological survey of New Hampshire has been the first of our state surveys which has possessed a special microscopist, a person who has turned his attention particularly to the study of the application of that instrument, aided by other means of research, to the investigation of geology. It is true that similar investigations have been made to some extent, by others as well as himself, for other surveys; but in no case hitherto have special collections been made systematically, and in such a manner that any very valuable results have been arrived at, for, in this branch of science as well as in others, a definite end should be had in view, and the specimens collected and the examinations made be for that end. It has remained for the state of New Hampshire to be the first to inaugurate a thorough microscopical survey of its geology and assistant branches of science,—paleontology,

petrology, and biology; and it is to be hoped that the results will be, therefore, proportionally valuable and interesting to science at large, and conducive to the welfare more particularly of the citizens of that state. It has been considered desirable, and, in fact, necessary to the proper understanding of the subject, that that portion of the work of the survey which comes within the province of the microscopist should be treated of under more than one head. Thus, at the present time, that part of his investigations which has a particular bearing upon paleontology, or the study of the remains of organized beings found stored up in the form of what are known as fossils in the various strata of the earth, will be treated of, while micro-petrology, or the examination of the minute structure of rock-masses by means of the microscope, will be considered at another time and by another hand, as the bearings of the two branches are so very different. The minor applications of the microscope to the subjects coming under the consideration of the survey will be gone into as opportunity offers and desirability requires. As it is to the study of the remains of the minute forms of extinct beings that micro-paleontology is at the present time particularly devoted, the structure of more highly organized beings not having been investigated in this connection to any very great extent, those smaller organisms, their life, history, habits, and relations to geology and the useful arts, will be herein considered; and we shall begin with a group of organisms whose remains constitute, in some parts of the world, strata of many feet in thickness, underlying cities, and, at other points, make up the greater part of vast mountain chains, and which have in former times played a very important part in the history of our globe. These are the Diatomaceæ.

PART FIRST.

A Sketch of the Natural History of the Diatomaceæ.

As a large majority of the persons into whose hands the present volume will come are ignorant of the characteristics of the group of organisms which it is intended to consider, that is to say, the Diatomaceæ, and as they occupy an important position in the scheme of the geologist, before going into their bearings on paleontology it has been thought

best, at the outset, to devote a few pages to a sketch of their natural history, presenting familiar and readily understood descriptions of their forms illustrated by figures, their habits, modes of growth and reproduction, and manner of occurrence in nature, so that the value of a knowledge of them may be comprehended, and the reader be able, if he desire so to do, to follow up their study and learn where they are to be found, and how they may be collected, prepared, and examined.

It is a remarkable fact that these beautiful and wonderful atomies, the diatomaceæ, are so little known to biologists in general, who, we find, have neglected in a remarkable manner to make themselves acquainted with the so-called lower forms of life, confining to a great extent their investigations to a study of the larger groups. This doubtless has arisen mainly from the fact that they cannot generally be seen and much less studied by the unassisted eye, but require, for the full elucidation of their anatomy and physiology, the most perfect appliances of modern skill, as epitomized in the achromatic compound microscope. Now, however, that the microscope is coming into more general use among scientific observers, it is to be hoped that some obscure points relating to this group of organisms, more particularly connected with their mode of reproduction, as well as the subjects of evolution, abiogenesis, and classification, which, it is considered, may be more thoroughly studied in these apparently simple forms than in the more complexly organized forms of existence, will be elucidated, or, at all events, have considerable light thrown upon them. Unfortunately, perhaps, the forms of the diatomaceæ are so beautiful and attractive, that, as they have been in the manner mentioned neglected by accomplished biologists, they have been collected, observed, figured, and described by totally incompetent persons, who, in very few cases, have possessed the training which would qualify them for undertaking the investigation of organisms of which so little is known, and whose position in the plan of being even is not thoroughly established. Hence, a great deal of that which has been published on this subject is totally useless, if it be not in many cases absolutely harmful, tending to confuse rather than simplify matters, and render the little that is known concerning their life-history obscure. The natural consequence has been that students of the diatomaceæ have fallen somewhat into disrepute, and, in some cases, observers have

been frightened away from a field of inquiry which was beset with so many difficulties at the outset. Under these circumstances it is hoped that the present sketch will recommend itself for perusal to every one interested in natural history, and at the same time introduce to many unacquainted with them an extremely attractive group of wonderfully constituted and beautifully sculptured beings. Those wishing to follow the subject up more thoroughly will find, in the works of Kützing, Smith, Rabenborst, Ralfs, and others,—a list of which will be given hereafter,—ample opportunities for making themselves acquainted with what is known concerning the diatomaceæ.

The Diatomaceæ, or, as they have come to be familiarly termed by those more or less acquainted with them, the Diatoms, have been so named from a genus called *Diatoma*, which received its name at a time when it was considered to be an animal, and was placed in a group to which a celebrated German naturalist, named Ehrenberg, gave the distinctive title of Polygastrica, or, polygastric animalcules, or, minute animals possessing many stomachs. The name *Diatoma* had been bestowed upon the organism in question from two Greek words, *dia*, through, and *temno*, to cut asunder, on account of its appearing as a number of minute, oblong boxes, attached, corner to corner, in such a manner as to form a zig-zag chain, and looking as if the chain had been formed from a ribbon-like band, partially broken across at intervals. After a while, when it came to be known that the group to which the name of polygastrica had been given was made up of many totally distinct groups,—some animals, some plants, and some neither one nor the other, but merely broken pieces of animals, plants, or minerals,—different forms were, one after the other, or, in some cases, many together, removed from this heterogeneous assemblage. Some, it was found, could be placed in divisions already known, but others had to be made into classes by themselves, and these newly constituted groups had to have bestowed upon them, as a natural consequence, appellations by means of which they might be distinguished and known. The *Diatomaceæ* was one of these apparently natural groups, and as all the forms, it was found, grew after a manner the same as the organism upon which the name of *Diatoma* had been bestowed, that is to say, by a partial or total splitting across, the distinctive name of *Diatomaceæ* was given to them, and they

were erected into a family by themselves, and provisionally placed in the animal kingdom. Very soon, however, it was observed that they possessed characters inconsistent with animals as then known, but more nearly allied to plants. For this reason they were soon removed to the vegetable kingdom, and, after a time, ranked as algæ, or water-plants which do not produce evident flowers. Yet there have been, and in fact still are, observers who think that these organisms were improperly removed from amongst the animals, and the consequence has been that, for a few years, they vacillated between these two kingdoms. By far the greater number of naturalists, however, have come to consider them as plants, and so they have rested up to a very late date. It has been within the last six or eight years that their true position has apparently been determined by a German naturalist named Haeckel, who considers that they possess characteristics which qualify them for a position, along with a few other minute forms of life, in a group separated alike from animals and vegetables, and to which he has given the name of Protista. Without, at the present time (for it would be out of place in a publication of the character of the present), going into the consideration of the reasons which have influenced the eminent German naturalist in his conclusions, suffice it that the author of this sketch coincides with him in his opinion, and considers the diatomaceæ to be neither animals nor plants, but Protista.

The diatomaceæ are inhabitants of both fresh and salt water, as well as that which is brackish by reason of its being subjected to the periodical influx of the water of the ocean, or that from springs and streams. They live in many cases attached to submerged objects, such as plants, rocks, or wood-work; but some species appear to be free, and unattached to anything. It is, however, likely, as has been shown by the present writer, that all of them spend a portion of their lives attached to substances below the surface of the water, whilst they have periods of freedom when they swim about, and in this way disseminate the species. Although we find them inhabiting both fresh and salt water, yet it would seem that there are certain forms which will not thrive in both of them. Thus, we find certain well marked species which would seem to be confined to the ocean, whilst others are only to be seen in running fresh water, and still others exist solely in quiet lakes. However, so little

has been done towards studying the local peculiarities influencing the distribution of these organisms, that we will dismiss the subject with this brief mention, merely pointing out that therein lies a field for investigation which will yield abundant fruit to the patient and conscientious student.

They are to be found in all permanent collections of water, but have never been observed in pools formed by the rain and liable to be dried up, and they may be looked for at all seasons, although, as might have been supposed, they appear in greatest numbers in spring and during the autumn. The hottest days of summer, at least in such localities as the present writer has examined, seem to be unfavorable to their growth (that is to say, in fresh water), but they have been gathered in midwinter from beneath the ice in the Hudson river, New York. In the ocean we find that season affects the diatomaceæ, as it does most organisms which, like them, live near tide levels; that is, they diminish in numbers as the cold of winter approaches, only to increase again in spring.

The structure of the diatomaceæ is very peculiar; and althought heir general outline can, without any very great difficulty, be made out by using a magnifying glass of moderate power, their ultimate anatomy is extremely difficult of elucidation, as will be exemplified further on. This can be readily understood when we know that the largest of them are not over eight thousandths of an inch in diameter, and that many, and those by no means the smallest, are only two ten-thousandths of an inch across. If the diatomaceæ possess an outer membrane, integument, or, we might almost say, skin, it is extremely delicate, so much so that it has not with certainty been detected as yet, although one or two observers think they have seen something that looks like such a seemingly necessary limiting portion of the individual. But we shall see hereafter that there are organisms very closely related to those we are now considering, which certainly do not possess limiting membranes, but whose whole substance is homogeneous, and made up of but one kind of substance of a semi-gelatinous consistence, and known to naturalists as protoplasm, meaning the simplest of all living matter. It is likely, then, that the diatomaceæ have for an essential base to their bodies this protoplasm; and, reasoning from what we know of allied organisms, it is within and from, in part, the substance of this protoplasm that the other portions of the individual

are elaborated, constructed, and built up. What appears to be the exterior membrane of a diatom is siliceous; that is to say, it is composed of the substance known commonly as silex, but called by the chemist silica. This is the same material as that which, crystallized, we find in rock crystal or quartz, and which, variously colored, constitutes flint, agate, jasper, amethyst, and various other minerals often used for ornamental purposes. Of course, this portion of the diatom is very hard, and on this account what we may with considerable propriety call the skeletons of dead individuals are used fôr the purpose of polishing metals, and similar substances, under the name of tripoli,—although it by no means follows that all tripoli is made up of dead diatom skeletons.

The typical form of a mature and perfect individual diatom is constructed after the following manner: The outer wall, consisting, as has just been said, of silica, is formed of two portions so fashioned that when these are united, as they are during the life of the organism, they form a little box, within which is enclosed the softer parts which go to make up what have been called the "cell contents," under the supposition that the diatomaceæ were "unicellular" organisms. Now that the old theory of cell organization has been very materially modified, this appellation had better be discarded, as it has been used (and in fact was constructed) for the purpose of describing a condition, of the existence of which there are considerable doubts. The whole diatomaceæous individual has been called the *frustule*, and under this designation we will speak of it here. Within the siliceous wall some observers have thought that they have detected a delicate membrane surrounding the rest of the contents, but it is doubtful if such a limiting membrane really exists; and, in fact, it is much more probable that the general mass of the contents is made up of protoplasmic substance, consisting, like such protoplasm usually, of a more or less semi-fluid material, without any differentiation of its parts from the centre to the exterior. Enclosed within the mass of this clear, colorless protoplasm are seen irregularly formed masses of a substance of a greater consistence, and of a peculiar light yellowish-brown tint: this is known as the *endochrome*. Sometimes the endochrome occurs in the form of two masses, but often there are many such masses. In either case, as a common thing, the particles of endochrome are so disposed as to lie near to the two portions of the siliceous wall which

constitute the top and bottom of the box. Besides this colored matter, which gives the peculiar tint to the diatoms when seen in mass at certain times, but apparently not at all periods of their existence, we find the diatom individuals to have scattered throughout their contents, but always within the layer of endochrome, one or more clear globules looking like oil. These have been called the "oil globules," and, when the diatomaceæ were ranked in the vegetable kingdom, were supposed to be the representatives of the starch found in the larger plants. Ehrenberg, who did (and, in fact, does still) rank the diatomaceæ among animals, considered these clear spaces to be stomachs, and fancied he had been able to feed these organisms on such colored matter as indigo, and see it enter these spaces. On account of their frequently being present in numbers, he constructed for the diatoms the name already spoken of,—Polygastrica, or many-stomached. There is no doubt that diatomaceæ will absorb indigo, or similar material, along with water, and thus their cell-contents may become tinted; but such taking into their interior, of matter, does not prove their animal nature, as all the Protista absorb solid nutriment, and, in fact, many undoubted plants, under certain conditions, do the same.

The typical form of a diatomaceous individual, then, consists of a little siliceous box with its cell-contents more or less colored of an olive-brown tint. The variation in form of the top and bottom of the box, which are known as the "valves," is very great, whilst the band uniting the valves, and called the "connecting membrane," or "cingulum," remains essentially the same, being merely a ring, narrower or wider as the case may be, and conforming in contour, of course, to the valve to which it is attached, and whose outline it then typifies. In the same way, the sides of a trunk form an oblong ring, and those of a pill-box a circular or oval loop. Thus, in the genus *Pinnularia*, the connecting membrane is oblong, with rounded ends; in *Coscinodiscus*, and the many similar genera, circular; in *Triceratium*, triangular; in *Amphitetras*, quadrangular, and so on, as can readily be understood, and will be made more plain when the various forms come to be seen in their integrity. As has been said, the outline of the valves varies very greatly, but is, for the most part, constant in each genus. We occasionally find, however, that the outline of the valve is the same in two or more distinct genera, which are then separable by means of some other character. The intimate

structure of the valve itself is very beautiful and characteristic, but we shall be able here to consider such structure in general terms only, leaving its more particular description until we note the peculiarities of a few typical forms, which will be described in detail, and illustrated by figures showing their outline and sculpture, as revealed by means of the microscope. The minute sculpture of the diatom valve is commonly spoken of as its "markings," and in all cases they are generally of a similar character on both valves. This, however, is not always the case, as we find in some genera which pass most, if not all, of their lives attached to objects like plants, sticks, stones, and the like, submerged in the water (fresh, brackish, or salt) which the diatomaceæ inhabit. In such cases, as they are dissimilar, and can be distinguished, it has become customary to call that valve which is next to the object upon which it grows the lower valve, and the opposite one the upper,—and if, as must often be the case when the diatom is fixed to the under side of a plant leaf as it floats upon the surface of the water, the position of the valves is reversed. In all cases the valves are convex at the edges, although they may be somewhat flattened near the middle, so that when the edges are in contact they enclose the cavity already spoken of, and which may be very shallow in proportion to its width, perfectly spherical, or several times deeper than wide.

The great point of beauty in the diatomaceæ, and what has attracted to them the attention of so many unscientific possessors of microscopes, is the symmetry and forms of these same sculpturings or markings found upon the siliceous envelope; and these vary in delicacy from comparatively coarse reticulations to such extremely minute dots that no microscope has as yet been constructed which will show us what is their true character, so that, as they lie side by side in rows, the siliceous cell-wall appears to be marked with extremely faint lines. But this is not all, for there are diatoms upon which even such faint lines have not been seen; but we know that they must be fashioned after the same manner as their brothers, and must, therefore, possess markings of yet greater fineness, and which time, it is to be hoped, with the aid of improved means of research, will reveal to the inquiring eye of the future observer. The great delicacy of some of the markings found upon diatom cell-walls, and the consequent difficulty of seeing them, has led to great rivalry in

makers of lenses for microscopes, and certain species have been selected and accepted as "test objects," by means of which the power of lenses to show their structure has been made evident. But as this has become a special department of microscopy we will pass it by, at the present time, with this mere allusion. These beautiful markings are, for the most part, hexagonal, that is to say, six-sided, or, at least, they are of forms derived from the hexagon, that being the form most economical of space under the circumstances. And it can be readily understood how this has come about, if we consider the matter after the following manner: It is well known that matter, by which is meant solid or semi-solid substance of any kind whatever, if left to itself uninfluenced by any outside force, as gravity and the like, will assume the globular form. Thus we find that the drop of water, of oil, or of metallic quicksilver, is round or spherical, or nearly so. So we can understand that the silica deposited as skeleton by the diatom would assume the spherical form. Likewise, the minute markings or granulations made up by those siliceous particles would, in a like manner, be at least spheroidal, be they elevations, as it is assumed by some observers, or depressions, as is thought to be the case by the majority of students. Now, supposing them to have a circular outline when they are far apart, if they are made to approach each other closer and closer until they touch, they, at last, by mutual pressure, will present a six-sided outline. That such would be the case may be proved, experimentally, in a very simple and, at the same time, elegant manner. Let a mass of soap and water be placed in a bowl, and a pipe like a straw be thrust down into it. Then if air be blown through the tube, keeping the end opposite to that placed in the mouth in contact with the bottom of the bowl, after a time the vessel will become filled with soap-bubbles all of about one size, and which we know, if they had been formed separately, would each have been perfectly spherical,—as, in fact, can be seen on the top where those which are outermost present an outer limiting surface which is part of a sphere. But we see plainly that these little globes have pressed upon each other to such an extent that they have lost their spherical outline, and have sides which are more or less plane. If, now, a plate of glass be pressed down upon the accumulation of bubbles in the bowl, many of them will be cut in two in such a way that we may see through the glass that their section is an almost regular

hexagon. In fact, such a collection of bubbles, thus cut in halves, looks very much like the transparent siliceous membrane of a diatom. It is impossible, however, to give any idea in words of the beauty of the diatomaceæ, and, in fact, the best of illustrations affords but a faint notion of them; they must be seen and closely observed to be fully appreciated. Their great interest to all students of nature will perhaps be understood from a perusal of this brief sketch, wherein their principal points of structure, habits, modes of occurrence, and uses, are set forth in such a way, it is hoped, as will be readily understood, and at the same time prove interesting to others than those intending to be students of these organisms.

Having now arrived at a pretty clear idea of the typical structure of diatoms in general, let us make ourselves more thoroughly acquainted with some of the various forms in which they make their appearance. If we take, as a representative of the usually free circular or discoid diatoms, the genus *Aulacodiscus*, we find the valves perfectly round in outline, and usually only slightly convex near the margin, the concavity for holding the cell-contents being thus somewhat flattened, its sides being limited as usual by the connecting membrane or zone, which in this genus is narrow. The structure of the siliceous material which goes to make up the valve is of the following character: On the exterior is a plate marked with coarse hexagons, which really are only net-like; that is to say, they merely constitute a hexagonal framework of boxes without tops or bottoms, set side by side, and arranged more or less regularly, so as to radiate from the centre to the edge of the valve. The radiant arrangement of these coarse markings varies in regularity in the different species of the genus, but in all is apparent. Inside of this coarsely marked plate is another, so that the large hexagons have the character of honey-comb; that is to say, the sides are perpendicular to the flat surface of the inner plate, which thus constitutes for them a bottom. And this inner plate is commonly, although not always, constructed after the same manner as the outer one, being set all over with small hexagons, which are so small that as yet their character has not been studied, but most likely it is similar to the larger ones, that is to say, being honey-comb-like; but its hexagons probably have not in their turn still smaller markings within them. At any rate, in most species of *Aulacodiscus*, both

those with two sets of hexagonal markings and those with only one set of coarse ones, we find that under, and often filling up the whole bottom of each hexagon, and therefore on the inside of the inner plate, is a little plano-convex lens of silica. That such is the case is readily proved by the images formed of the source of light, as a candle, by the little lenses; and in fact it would doubtless be possible to measure their focus by means of a graduated fine adjustment to the microscope, such as is found on the larger instruments. Sometimes the sides of the large hexagons are not quite perpendicular to the inner plate, but approach each other as they descend, so that the bottom of the cavity becomes concave; and, as the convexity still occurs on the inner surface of the inner plate, we have a meniscus lens of silica formed,—that is to say, a lens which is still thickest at the centre, and therefore one which converges light like the plano-convex one more commonly found. The effect on light passing through such a diatom is very much the same as in the first case mentioned, but sufficiently different to be distinguished. Though these peculiarities of structure can be made out by a careful observer in *Aulacodiscus* and a few other genera, on account of their size and coarseness of structure, yet they can be seen only with difficulty in others, and in most diatoms cannot be shown at all. And this can be readily understood when we remember that markings of any kind upon many species can only indistinctly be seen when the best optical appliances for illumination and the finest microscope objectives and occulars are used. In fact, it has been for the purpose of exhibiting such markings that objectives have been specially made and apparatus invented, as has been already said.

The sculpture of the siliceous cell-wall just described is not peculiar to the *Aulacodiscus*, but is found in many other genera. This particular genus, however, is remarkable for possessing what have been called, for want of a better name, "feet." These consist of tubular masses of silica projecting outwards from the cell-wall, and usually placed near to the margin of the valve. In some species the portion from which the feet project is somewhat raised immediately under each foot, or in the form of a ridge all around the valve. Within this portion the valve is either plane, concave, or undulate, although the central portion is usually somewhat raised. The feet project outwards at a greater or less angle, and

are either short and stout or long and slender, varying in this respect in different species. They also vary in number from one upwards, the number being constant in some species, while in others it varies very greatly. Usually the outermost end is somewhat swelled into something like a knob, and within this part the central canal, running through the foot, also swells into a spherical cavity. When a perfect specimen of an *Aulacodiscus* is examined on what is known as its "front view," that is to say, with the edge of the valve presented towards the eye, the presence of the feet makes the appearance of this diatom very characteristic. The description of this genus has been thus full, because the beautiful complexity of the diatomaceæ could thus be made evident, and many points of structure dwelt upon at the outset. So when we come to describe a few of the other forms as types, their resemblance to or variance from *Aulacodiscus* will be noticed.

The genus *Coscinodiscus* has the same general characters of outline and sculpture of markings as the genus just described, but is destitute of "feet," and, therefore, of the raised portion upon which they are placed. The two membranes are present, but the inner one is smooth. Both *Aulacodiscus* and *Coscinodiscus* are inhabitants of salt water, although there is a minute form, usually classed as a *Coscinodiscus* and called *minor*, which has been seen in fresh water; but it is now pretty well ascertained that it is not a true *Coscinodiscus*, but belongs to the genus to be described next.

In *Melosira*, the frustules have a general resemblance to *Coscinodiscus*, and are frequently mistaken for specimens of that genus, especially when dead and detached one from the other. Usually, however, the valves are so much more convex when viewed edgewise, that the whole frustule may approach in form a sphere, as is the case in the species chosen as an illustration. It however differs widely from *Coscinodiscus* in having its frustules united, by means of their valves, into long chains, which are quite flexible, so that they wave about in the moving water. Some species have the valves more flat, and then the live plant looks like a number of pill-boxes attached together. Some species are peculiar to fresh water, whilst others are found in the sea; but it would seem that a few of them can become acclimated to and live in either kind of water.

Actinoptychus, another beautiful genus, contains several species which

are extremely graceful in sculpture. In form it is discoid, on what is known as the "side view," but, unlike any of those we have seen so far, the surface of the valve is divided into segments which radiate from the centre, and are arranged alternately elevated and depressed, so that on a front view the frustule appears undulate. When we look straight down upon the valve, it has very much the appearance of a wheel. In some species the markings of the raised segments are different from those on the sunk portions, while others have the markings of the same character all over the valve. They are, however, always of the same general character as those described as occurring in *Aulacodiscus*. This is likewise a marine genus, and some of the most beautiful species belonging to it have been found as yet only in the fossil state.

There are many other discoid forms which we cannot stop to describe, but must pass on to consider some other genera.

Nearly allied to the true discoid diatoms, and in fact having a few circular species, are two genera which it will be well to describe here. One of them is called *Biddulphia*, and is found only in salt water, although one species was seen by the late Prof. Bailey in the Hudson river at West Point, where the water is not all salt; but, strange to say, the tide reaching up as far as this, the salt water creeps up under the fresh, so that at this point salt and fresh water forms of vegetation appear alongside of each other. *Biddulphia* grows in chains attached to submerged objects, more commonly the larger plants. It has valves either orbicular, elliptic, or more or less pointed in two directions, and approaching in outline to the boat-shaped genera to be presently described. In fact, the outline of the valve in *Biddulphia* varies very greatly, as is seen by the figures given. At two opposite points on the valve are projections upwards very much like the feet of *Aulacodiscus*, and, in fact, they may be considered their analogues. So when *Biddulphia* is looked at on a front view, it looks like a number of little wool-sacks; and the species which Prof. Bailey found at West Point, and which is not very uncommon along the Atlantic coast of the United States, has very much that appearance, especially as the frustules grow in the form of a chain, with these projecting portions united, often alternately, so that the chain becomes of a zigzag form. Sometimes the surface of the valve also bears upon it certain spines, varying in number in different species, and usually

placed near to the centre or at points midway between the centre and the edge, and half-way between the horn-like projections.

In outline, *Biddulphia* passes into a genus known as *Triceratium*, which, as its name indicates, is provided with three projecting horns or corners. In fact, what may be called the normal form of its valve is triangular, having three horn-like projecting portions like the two in *Biddulphia*. But although the commonest outline is triangular, we find certain species varying to such an extent as to have examples with four, five, and even six sides,—in this respect resembling *Aulacodiscus*, whose number of projections, or "feet," vary in the manner described. And there is a genus called *Amphitetras*, which apparently only differs from *Triceratium* in the fact that its normal form is with four corners. In truth, we find occasionally specimens of *Biddulphia* with three corners, *Triceratium* with four, five, six, and even nine corners, and *Amphitetras* with five corners, so it becomes extremely difficult to draw lines of distinction between these three genera. Besides this, we find that among themselves the species of *Triceratium* differ in minor characters; some have the sides convex, becoming more and more so, until at last we have a perfectly circular outline still retaining the three projecting horns. Then we find them with sides straight, then more and more concave, until the valve appears to be but three arms united by a very small body. Some have undulate sides. The front view is as various as the side view. In some the processes are nearly level with the surface of the valve, while others have them considerably elevated, and attenuated into spines. So, again, in this beautiful genus, the sculpturing of the valve is very various. We have coarse hexagonal reticulations, with or without finer ones within them, fine hexagonal markings, circular, dot-like, radiant or curved depressions, in some cases of such delicacy that high-power glasses are required for their elimination. Then, again, we have large, heavy bars of silica projecting across the valve in different directions, merely cutting off the corners, or dividing the central portion in various ways. In short, *Triceratium* is one of the most variable as it is one of the most beautiful genera of the diatomaceæ. It is found living in the ocean, growing in chains attached to algæ and shells, after the manner of *Biddulphia* and *Melosira*. Some of the most beautiful species have been as yet found only in the fossil condition in certain so-called "infusorial" earths.

As has been said, the species of *Biddulphia* vary very greatly among themselves, until we have them approaching the boat-like form in outline, and in this way they are connected with the next group of diatoms, which we now come to consider. These are all more or less quadrangular in outline, or, rather, we might describe them as elongate, with more or less parallel sides, and having their ends acute or rounded. The genera belonging to this group are very numerous, but we shall describe only a few of them. It is a remarkable fact, that, almost with the exception of some of the *Melosiræ* and allied cylindrical forms, the discoid, two-, three-, four-, five-, and six-cornered genera are confined to salt water; but the boat- and stick-like forms are found in both fresh and salt water, so that in our streams and ponds we find the "naviculæform" and "bacillar" genera, as they are called, almost unmixed with circular forms. A few species of *Melosiræ*, and an allied genus called *Cyclotella*, are found occasionally intermixed with the boat-like ones, and rarely alone in lakes and fresh-water streams. So we already see that, by examining the species of diatoms, we can say with considerable certainty whether a piece of water be fresh or salt, and, if found in a fossil condition, whether the earth, of which they make up a part or the whole, was thrown down from a now extinct ocean, lake, or river. Our knowledge of the habits of the diatomaceæ is hardly complete enough as yet for us to tell exactly the character of lake, river, or ocean in which the diatoms grow; but already we have learned that certain forms are found on mountain tops, others in swift streams, and so on.

Taking *Pinnularia* as the first type of the naviculæform, or boat-shaped diatoms, we find it to be, of course, made up of two siliceous valves and a connecting membrane. The valves are boat-shaped in outline, sometimes with the sides parallel, and the ends pointed or rounded off. Frequently the sides are convex or bowed outwards, bent inwards, or undulate; but all of the various species, and they are very numerous, preserve the general characteristic boat-like form. The valves in this genus are commonly very convex, so that when looked at on a front view or endwise, the edges are distinctly rounded off. Running down the middle portion of the valve from one end to the other is a blank space, which, at each end and at the centre, expands into round nodules projecting into the cavity of the frustule, as likewise does the

blank strip itself. In fact, this strip, with its end and middle swellings, constitutes a thickened part of the valve, and they have by some writers been called the "median line," and "central" and "terminal nodules." Considerable confusion has arisen in the nomenclature of what might be called the osteology of the diatomaceæ. This central thickened band is usually, if not always at some period in the life of the individual, traversed by a canal which runs the whole length of the clear space, but in the thicker ends terminates in enlargements, and is divided into two sections at the centre of the valve, where, likewise, it ends in two round cavities. The end enlargements of this canal have also been called "terminal nodules," and the swellings near the centre have been called "central nodules," as well as the parts just described. Lately it has been proposed to call the tube the "central canal," and by this name we shall designate it in this sketch. At one period in the life of the diatom it would seem that this canal is open outwards down its whole length; at least, such is the belief of some observers; but the writer has never been able to satisfy himself that such is the case, for in some of the *Pinnulariæ* he has noticed that the central enlargements of this canal open, by means of trumpet-shaped tubes set at right angles to the course of the canal, into the general cavity of the frustule, and that the terminal expansions, in a like manner, have a communication outwards at the ends of the valve. It is his opinion that this canal has something to do with the motion of the naviculæform diatoms, which always sail about in a direction parallel to their longest axis. The central canal, when the diatom valve is dead and dry, is filled with air, and then,—on account of the effect produced upon the light as it is transmitted through the object to the microscope,—appears black, or nearly so, if the objective employed is a good one, and more or less colored when an inferior one is used. The markings found sculpturing the valve of *Pinnularia* are different from what we have seen to occur in any of the genera described so far. We find no large hexagons nor finer ones here, but, instead, the valve is marked on each side of the median blank space with lines which indicate elevations in the form of bars or corrugations more or less parallel to each other, and set at nearly right angles to the central canal. These bars, or "pinnulæ," as they are called, reach from the edge of the valve over the convex margin, and up to the median blank space, where they stop in rounded off extremities.

There is a genus very closely allied to *Pinnularia* which has the same general form, except that in many of the species the sides slope off straight towards the somewhat acute ends, so that the whole valve is quadrangular in form. On account of the thickened portion at the centre of the valve being widened out so as to extend almost or quite across the valve as a band, and thus, with the median blank space, form a cross, it has received the name of *Stauroneis*. The markings on the valve, however, are not those found on *Pinnularia*, but consist of minute depressions, or dots set in lines, which run usually somewhat sloping from the middle portion to the edge. These rows of dots are usually known as "striæ," and are often extremely fine, so much so that in some species in which they occur they are very difficult to demonstrate, and hence the diatom becomes a very good "test-object." In *Navicula*, the genus which has by far the largest number of species, inhabiting fresh, salt, and brackish water, we have *Stauroneis* without the central cross bar, but merely the blank longitudinal space found in *Pinnularia*.

The variation in outline and in other respects, among the several hundred species which have been grouped together under the generic name of *Navicula*, is very great, so much so, in fact, that it would seem reasonable to believe that several genera must have been unconsciously fused together. And such is the opinion of the present writer, in which he rather agrees with some of the older writers on the diatomaceæ.

There is a genus which at one time was included in *Navicula*, but which has of late years been separated therefrom, and is known as *Pleurosigma*. It looks like a *Navicula* which has been twisted so as to bend the two opposite sides of the valve in different directions. Hence it has somewhat the form of an S, as its name indicates. It has a central canal like the other naviculæform diatoms; but the blank space through which it runs is very narrow. The central expansion is generally present; but the terminal swellings are not so evident. On this account, although in *Pinnularia* and other genera, in which they are pronounced, the terminal expansions of the blank, thickened portion have been called "terminal nodules;" in *Pleurosigma*, where they are not so apparent, that name has been applied to the swelled ends of the central canal,—an example of the unscientific manner in which the diatomaceæ have been treated by many who have written about them.

The markings on the valves of *Pleurosigma* are peculiar, and different from those found upon the other naviculæform diatoms considered. The genus can be and is usually divided into two groups, distinguished by the character of the markings. In the first group the valve is covered with dots set all over the surface in such a way that they are in lines at equal distances apart, running from the central canal to the edge of the valve. But the next row starts, as it were, half a dot behind the previous one: therefore its dots alternate with and come between those of the first line, and so on, so that the dots are at equal distances apart all over the valve, but, when traced across the valve, are in straight lines, and, when traced lengthwise of the valve, are in zigzag lines. As these dots are coarse and set far apart in a few species, they can then be seen to be circular, but, when they approach each other closely, they appear to become, by mutual compression, as would be the case if such were to occur, hexagons. In fact, it has been one of the difficult matters to solve concerning the diatoms, and one on which observers have differed for a long time, as to whether the markings on certain species of *Plcurosigma* are circular or hexagonal. Hence one species, especially named *Pleurosigma angulata,* has been selected as a "test object" for lenses of moderate power. But the second of the two groups into which *Pleurosigma* is divided has its markings arranged somewhat differently. In this group the dots are set in straight lines, if they be traced either across or lengthwise of the valve; that is to say, instead of being alternate, they are opposite in contiguous rows. Among themselves the different species of *Pleurosigma* vary somewhat: thus in many the sides run in one unbroken line from end to end, being only swelled out at the centre. In *P. angulata,* and still more so in *P. quadrata,* the bowing out at this point is decidedly angular. In *P. Balticum,* a species originally found in the Baltic sea, and hence the name which was given to it, but which has since been found pretty much all over the world, the sides are straight and parallel until near the ends, when they are curved over so that one end of the valve points to the right, while the other is turned to the left. *P. angulata* and *P. quadrata* belong to the group in which the dots of the markings are arranged alternately, while *P. Balticum* has its dots set regularly and opposite to each other. *P fasciola* differs totally in outline from any of those described. The main portion of its valve is in shape like a *Navic-*

ula, being almost oval, but pointed at each end, and with a central canal running down the middle, just like a *Navicula;* in fact, it may be said to be almost shuttle-shaped; but from each extremity projects a long, horn-like portion, into which the central canal is continued, and which is curved one to the right, the other to the left, thus completing the sigmoid form necessary to constitute a member of this genus. Some species of *Pleurosigma* have markings of such extreme fineness that it becomes very difficult to see them unless the microscope employed be of the best quality. A few species are found in fresh water, but for the most part they are inhabitants of the brackish water of swamps and similar localities.

Some species of diatoms present us with examples of a peculiar structure not found in all. Thus, when we look at certain species of *Stauroneis* from a front view, we see at the ends and just below the terminal nodules, as a part of the valve, and just where it joins the connecting membrane or zone, a stout siliceous structure projecting a short distance into the cavity of the frustule like a shelf, but more so at the ends than at the sides, where it becomes so shallow as to be hardly apparent. When we look down upon the valve, or view the diatom on what is known as the side, we see that this projecting portion forms a ring all around the cavity, widest at the ends and narrowest at the centre, where it is hardly, or in some species not at all, perceptible. This has been called the "septum." In *Triceratium*, we find it appearing only as slight projecting shelves at the corners. Some genera have it very strongly developed, and projecting very far into the cavity, so that the two septa divide it into three distinct portions. Some genera have more than two septa, and in such cases they are not fused with and form part of the valves, but are attached to separate rings which lie between the edges of the valves and the connecting membrane or zone.

Septa are very marked characters in a genus named *Grammatophora*, which is found in chains of many frustules, united corner to corner, and attached to algæ in the ocean on almost all sea shores. The valves are shaped somewhat like a *Pinnularia*, but have the striæ, as the rows of markings have been called, running straight across, and extending quite up to the ends. The septa are four in number, and extend almost across the cavity of the frustule, leaving only a small opening of communication at the centre. Besides, although some species have them straight,

in most they are undulate, so that on a front view they look somewhat like written characters, which has led to the name *Grammatophora* being given to the genus.

Nearly related to the genus just mentioned is one known as *Rhabdonema.* It likewise is found growing in chains attached to algæ, and similar submerged objects in the ocean. In this the septa are not continuous, but look as if they were punctured with several holes. The two last mentioned genera are attached to their supports by a small gelatinous cushion, but there is a genus named *Achnanthes*, in which this cushion is lengthened out into a long stalk, and as it is attached to one of the corners of the frustule, the whole individual looks very much like a flag floating out straight from a staff. This stalk is called the "stipes," and is remarkably developed in other genera. Thus, *Gomphonema* consists of a number of wedge-shaped frustules attached by their pointed ends to long and forked stalks, while in *Synedra* the stipes has again shrunk down to a cushion. The frustules of *Synedra* are like little sticks attached to the cushion by one end, and sticking out on all sides like the spines of a porcupine.

There are many other forms which the various genera of diatoms present, but we have had space only to describe and figure a few of them. The possessor of a microscope will soon, if he searches, come across others; and if he is encouraged to ask for more information concerning the beautiful atomies he sees, as it is to be hoped will be the case, he will be able, in the works of W. Smith, Rabenhorst, Kützing, Ralfs, and others, to find them more fully described, and better and more thoroughly illustrated. So to those works we must refer the reader who desires to learn more than we have been able to tell him in this little sketch concerning the diatomaceæ.

PART SECOND.

Movements of the Diatomaceæ.

It has been said that it is extremely probable that all species of diatomaceæ are at some period of their lives free, while for a short period perhaps for some, but always for some time, they are fixed or attached to some submerged object, as rocks, plants, woodwork, or similar substances. This opinion is not held by all observers; so much so that many,—and

W. Smith, the author of the Synopsis of the British Diatomaceæ, among that number,—have classified them in such a way as to constitute two great groups, namely, those which are free, and those which occur attached. It would seem most natural that those forms which commonly present themselves attached should become free at some period of their existence for the purpose of disseminating the species, for we do not find that the diatomaceæ produce seed which may be wafted about by the motion of the water, or young which are specially characterized by possessing organs of motion, so that this phenomenon may be accomplished. However this may be, it is a fact that many of them possess peculiar movements, produced by and inherent in themselves, and which have from the earliest times, when they were first observed, attracted the attention and aroused the wonder of possessors of microscopes. And when these seeming sentient movements are watched by means of the magnifying glass, it is not to be wondered at that many observers have been disposed to class them among animals possessing complicated organs of locomotion, digestion, and reproduction, if not reasoning powers to guide and direct those organs. And this power of active movement is not confined to those forms alone which are usually seen free, for many of the fixed forms, if detached from their support, will immediately take upon themselves motions precisely similar to those of their normally free brethren.

The extreme liveliness of some of the diatomaceæ has been considered by many as proof of their animal nature; but when we know that the seeds of many large and acknowledged plants growing in water, namely, the algæ, are even more active in their motions than our little friends, and, as in the case of those plants, this motion is evidently for disseminating the species, so we may naturally believe that some similar provision is made for the wide spreading of the diatomaceæ. If we watch, by means of a good microscope, an individual belonging to the genus *Navicula*, in which the form, when viewed in the direction which is usually presented to the eye, is that of a double-prowed boat, something like an Indian canoe, we find that it moves after the manner of a boat, but with either prow forward, as happens to be most convenient, apparently, for, after moving in one direction for a few seconds or minutes, it will immediately return upon its course, now propelling the other forward. And although

in a few species, and those seemingly the larger, the motion is a steady progressive one, yet it is by far commoner to find that it is unsteady and trembling, as if it were the tottering steps of the infant, or of extreme old age. *Navicula* is one of those genera which are usually classed among the free forms, and in them all, with perhaps one or two exceptions, when they have any progressive motion, it is that which we have described. There is a genus which has very much the form of a horse saddle with the two flexures, and known as *Campylodiscus*, in which "the motion never proceeds farther than a languid roll from one side to the other."

As has been remarked, the earlier observers of these atomies, being insufficiently informed on the subject of the economy of the vegetable kingdom, considered the possession of the power of spontaneous motion by any being indisputable evidence of its animal nature; and, on this foundation, it became easy to rear up a mass of proofs that the diatomaceæ were certainly animals. The space within the two-valved shell, like an oyster or clam, was the animal matter furnished with special organs, if not with muscles, by means of which the movements were accomplished. Of course, the many clear vacuole-like-looking spots of oily matter were the stomachs, and, with the imperfect microscopes of the time, observers were (they thought) able to see the protrusion of a "foot" like that upon which the snail travels, through the central portion, which looked to them like a round opening, but which we now know to be a thickened portion of the shell. A late observer has asserted that he has seen, along the so-called "median line," an appearance indicating the protrusion of an organ or series of organs of some kind; but as others, equally competent microscopists, have not been able to satisfy themselves that there are such organs, this gentleman's assertion can hardly be said to be proven. There are still a few microscopists who hold to the belief in the animal nature of the diatomaceæ, although by far the majority rank them as plants. One gentleman in England says that he has seen (and, what is more, figures) the cilia, or hairs, which move about like arms, and by means of which these creatures change their place. Unfortunately, he first takes the animal nature of the diatomaceæ for granted, and then attempts to prove the existence of the cilia as organs of locomotion.

It will be naturally supposed, from what has been said on the subject, that the mode in which the motion is caused is not decidedly known; but however that may be, it is a remarkable characteristic of these creatures, and, although in most species it is regular and uniform, in some it takes place as a series of jerks. It would seem that it could hardly be called a voluntary motion, or, at least, that if it be so, the faculty governing and directing it within the creature is of a low order, or one which responds to stimulus in a very sluggish manner; for if an obstacle of any kind occur in the path of a moving diatom, like a *Navicula*, it is not avoided; but, on the contrary, if it be small enough, it is thrust aside; or, if it be too large, the diatom is arrested in its career for a certain length of time, or turned aside in its course. If it be stopped, it is a remarkable fact, noted by English observers, that the diatom waits exactly the length of time it would have taken for it to perfect its forward progression to the greatest extent, when it returns on its path again. In many species, however, the motion is not so regular as this, and the little creature goes tottering along its way. It has been remarked by one author that "the movements of the diatomaceæ appear rapid and vivacious under the microscope; but it must be remembered that the high powers usually employed in the observation of these minute organisms magnify their motions as well as their bulk." Using a seconds watch, and timing several species exactly, it has been found that one of the most rapid, known as *Bacillaria paradoxa*, took a whole second to move over one two-hundreth of an inch; and that one of the slowest, named *Pinnularia radiosa*, in the same space of time only travelled one thirty-four-hundredth of an inch;—so that the quickest would take three minutes to travel an inch, while its slowest relative would require a full hour to perform the same feat. But although a few observations of this kind have been made, we have by no means arrived at a knowledge of the rate of movement of these atomies, for it varies under different circumstances, as apparent condition of health and surroundings. Heat appears to accelerate as cold retards it; and yet I have seen *Bacillaria paradoxa* very lively when taken from beneath the ice on a cold winter's day. It is a curious fact, that often, as we watch a diatom sailing across the field of the microscope, it comes in contact with an obstacle, as a grain of sand. If it cannot move it, or pass under it, or, by a little shifting, around

it, it waits exactly the length of time it would have taken for it to perfect its forward progression, when it returns on its path again. But this takes place only with such species as have a regular backward and forward motion; most of them are extremely erratic in their ways. As an illustration of the regularity of movement of the diatomaceæ, let us consider one of those species just mentioned, namely, *Bacillaria paradoxa.* This creature has a motion of its own, which is so peculiar, and at the same time so incomprehensible in its mode of accomplishment, that it well deserves a more particular description. This species is somewhat of the form of a straight ruler, when we consider the single individual, or, at least, it looks very much of that form, as commonly seen. But a careful examination shows it to be made up of two long and narrow boat-shaped valves, united together so that the keels project outwards opposite to each other, and enclose within their united bodies the general cavity of the frustule. When in a living state, the compound individual, or colony, whichever we may choose to consider it, consists of a number, more or less great, of these double boat-shaped frustules, united one to the other at their keeled sides; but the mode of union is entirely unknown, and, from the extreme freedom of motion which each frustule of the colony enjoys, it is hard to imagine what its character is. Thus united, they form a filament which is generally found floating freely in the water of brackish ditches within reach of the influence of the sea. But I have seen it in perfectly fresh water, far up the Hudson river in New York state.

The movement has been well described by an English observer, Mr. Thwaites, and I cannot do better than quote his words. He says,—

When the filaments have been detached from the plants to which they adhere, a remarkable motion is seen to commence in them. The first indication of this consists in a slight movement of a terminal frustule, which begins to slide lengthwise over its contiguous frustule; the second acts simultaneously in a similar manner with regard to the third, and so on, throughout the whole filament; the same action having been going on at the same time at both ends of the filament, but in opposite directions. The central frustule thus appears to remain stationary, or nearly so, while each of the others has moved with a rapidity increasing with its distance from the centre, its own rate of movement having been increased by the addition of that of the independent movement of each frustule between it and the central one. This lateral elongation of the filament continues until the point of contact between the contiguous frustules is reduced to a very small portion of their length, when the filament is again contracted

by the frustules sliding back again, as it were, over each other; and this changed direction of movement proceeding, the filament is again drawn out until the frustules are again only slightly in contact. The direction of the movement is again reversed, and continues to operate in opposite directions, the time occupied in passing from the elongation in one direction to the opposite being generally about forty-five seconds. If a filament while in motion be forcibly divided, the uninjured frustules of each portion continue to move as before, proving that the filament is a compound structure, notwithstanding that its frustules move in unison. When the filament is elongated to its utmost extent, it is extremely rigid, and requires some comparatively considerable force to bend it, the whole filament moving out of the way of any obstacle rather than bending or separating at the joints.

This is not always the case, as I have myself frequently observed, as the filament often becomes bent by the force of its own motion. And there is one other fact which seems to have escaped the notice of Mr. Thwaites, and which adds considerably to the interest of an exhibition of this plant while in motion. After the extended frustules have returned to their normal position in the filament, so as to form a ribbon-like combination again, and just at the time when they are about to start on their way in the opposite direction, there seems as if a considerable amount of force were necessary to get them started past this point, for this force is very apt to dislodge the whole filament and swing it entirely round, so that that end which was, we may say, pointing towards the right hand, now points to the left. The consequence is, that now, when the frustules proceed on their path towards the opposite side of the filament from which they projected previously, they, in reality, extend towards the same side of the microscope as they returned from. This motion often continues to be exerted, so that the whole filament is periodically swung around on its centre as the frustules return to their places, and become again parallel one to the other. Often and often have I spent hours looking at this marvel of nature; the motion without apparent cause or mode, an invisible joint, which, as a friend of mine (an engineer) once remarked, would be a fortune to any one who would discover it, for here we have several sticks forming the bundle, moving over each other without separating, and yet the use of the highest powers of the microscope has failed to detect the means of their union into one mass, or composite group, of individuals. The more often I watch *Bacilleria paradoxa*, the more it puzzles me. Not long since I saw one specimen (of course, I

mean one bundle of individuals) slide out to its utmost limit across the field of view, and then, becoming entangled with others, which likewise were made up of many individuals, some eight or ten of its frustules were twisted around, almost off from the rest, so as to lie at right angles to them; and when the group containing the largest number of frustules receded to their former position, which they soon did, the eight or ten seeming, by the act of twisting, to lose their power of motion among themselves for the time being, were dragged along in a helpless condition, and twisted completely around one revolution, so as thereafter to fall back again into their places, when all went on again as usual,—that is to say, the regular motion of all the frustules over each other succeeded. Now what kind of a joint can it be that permits of such eccentric movement? The motion of all diatoms is accelerated by a moderate heat, so that specimens gathered during the winter months, and remaining either quiescent, or only exhibiting very slight motion when viewed by means of the magnifying glass of the microscope, may be made to move vigorously by the cautious application of warmth, as by placing them in a warm room, or by holding the glass slide, upon which they are, upon the palm of the hand for a short time.

PART THIRD.

Mode of Growth of the Diatomaceæ.

When we speak of the growth of the Diatomaceæ, it must not be confounded with the reproduction of the organisms, although modern physiologists are coming to understand that growth or increase in volume, and reproduction or increase in number, are very nearly related, if they be not but modification, in degree and in direction, of a force acting within and essential to the existence of living beings.

We have seen what the structure of the outer coat or siliceous skeleton of the diatomaceæ is. Let us now, before asking how they grow or increase in dimensions, learn what is known with regard to their internal economy, that is to say, the anatomy of their softer parts. Unfortunately, on this point our knowledge is extremely unsatisfactory, and it even appears, as has been already hinted, that the result of modern investigations would be to upset a great deal of what we have up to a late date considered as settled in connection with this point.

Immediately within the siliceous skeleton of a diatom is supposed by many to be a membrane or skin which bounds and limits the soft parts of the organism; and it is this membrane, say those who believe in its existence, which secretes or forms the wonderfully sculptured epiderm we have been considering. Some observers think that there is also an outside membrane, and that it is in it that the silica accumulates. But as many good observers have been able to see neither of these membranes in the living diatom, and as even the believers in their existence acknowledge that they are extremely difficult of exhibition, most likely the fact is that the real individual matter of the diatom is a mass of structureless protoplasm, which deposits near its outer portion the silica it has absorbed from the surrounding water. Within the protoplasmic mass is the endochrome or colored matter we have already spoken of, and which is most commonly disposed in two portions contiguous to the two valves. In the clear central portion there is often to be seen a little sac or vesicle, which is quite transparent, except at one part, where a minute dot is seen. This vesicle is considered to be the "nucleus" of the diatom, while the dot is the "nucleolus," both of these things being required in a cell constituted under the type established by a German observer named Schwann. But now that Schwann's typical cell, consisting of a "cell wall" containing "cell contents," wherein are found a "nucleus" and often one "nucleolus" or several "nucleoli," is known to exist rarely, we are not surprised if we do not find all of these parts present in a diatom. And now that we understand the internal anotomy of the diatom, without taking into consideration disputed minutiæ of structure, we can see how the individual grows.

Schwann has shown us what he considers cell growth to be, and it is what is known as "cell subdivision." That is to say, the cell itself is stable as to size, but increase of volume occurs by its dividing into two, and these two into four, and so on, so that if the resulting cells remain united to each other there will eventuate a true increase in bulk, and eventually a large organism like a tree or a man may be formed. But such is not the way that the diatom grows, for it is not a polycellular, but a unicellular organism. There is a large group of very simple plants, even more simple in structure than the diatomaceæ, for they have no elaborately sculptured siliceous cell-wall, which are known as *Protophytes*,

and in the life history of one of these we shall be able to study the simplest expression of cell growth. Dr. Carpenter, whose valuable treatise on the microscope is to be recommended to all intending to use that instrument, has epitomized what is known on this subject so well that I cannot do better than to give it in his own words. He says,—

The life-history of one of these unicellular plants, in its most simple form, can scarcely be better exemplified than in the *Palmoglœa macrococca* (Kützing)—one of those humble kinds of vegetation which spreads itself as a green slime over damp stones, walls, &c. When this slime is examined with the microscope, it is found to consist of a multitude of green cells (Fig. A), each surrounded by a gelatinous envelope; the cell, which does not seem to have any distinct membranous wall, is filled with granular particles of a green color; and a *nucleus*, or more solid aggregation, which appears to be the centre of the vital activity of the cell, may sometimes be distinguished through the midst of these. When treated with tincture of iodine, however, the green contents of the cell are turned to a brownish hue, and a dark brown nucleus is distinctly shown. Other cells are seen (B), which are considerably elongated, some of them beginning to present a sort of hour-glass contraction across the middle; in these is commencing that curious multiplication by binary subdivison, which is the ordinary mode of increase throughout the vegetable kingdom; and when a cell in this condition is treated with tincture of iodine, the nucleus is seen to be undergoing the like elongation and constriction. A more advanced state of the process of subdivision is seen at C, in which the constriction has proceeded to the extent of completely cutting off the two halves of the cell, as well as of the nucleus (I), from each other, though they still remain in mutual contact; but in a yet later stage they are found detached from each other (D), though still included within the same gelatinous envelope. Each new cell then begins to secrete its own gelatinous envelope, so that, by its intervention, the two are usually soon separated from one another (E). Sometimes, however, this is not the case,—the process of subdivision being quickly repeated before there is time for the production of the gelatinous envelope, so that a series of cells (F) hanging on one to another is produced.

Now the diatomaceæ grow in a manner precisely similar to that just described as taking place in *Palmoglœa.* This subdivision of the cell, so that the new individuals are formed from one in the diatomaceæ, results in the production of a series of frustules almost identical in all particulars with the original individual. In most cases, if not in all, the new individuals differ from that from which they sprung in two marked respects: First, they each possess one old and one new valve; and, secondly, the new valve is smaller than the old one, so that the two valves of all diatoms differ somewhat in dimensions, although alike in other respects.

As the siliceous exterior skeleton of the diatom does not permit of its expanding in all directions, the consequence is that when it absorbs nutritive material, increases in bulk, and proceeds to subdivide, it must multiply its bulk in one direction only; and, as the two valves are capable of being separated one from the other along the line of junction with the connecting membrane, it is in that way that the splitting up of the cell into two new ones takes place. The existence of the connecting membrane in the perfect diatomaceous individual, before subdivision starts, is denied by many. Under those circumstances, the siliceous skeleton consists of only two parts, the valves, to which, as soon as subdivision sets in the third portion, the connecting membrane is added. In *Palmoglœa* we have seen that the perfect cell subdivides by a process which shows itself by the bending in of the cell wall, if there be one, or by the periphery of the mass, if there be no limiting membrane. In this way, at first, two united and similar halves, and thereafter, two separate individuals, are formed exactly alike in all particulars. The nucleus and nucleolus, if there be one, of the diatom subdivide at the same time; and, to make room for the increasing cell-substance, the enclosing valves separate from one another, the space all around between them being closed in by the new hoop of siliceous substance, the connecting membrane which now makes its appearance and grows by additions to its two edges, as the accumulation of pabulum by the growing individual goes on. At the same time, two new valves have been forming exactly like the two old ones, except that in consequence of their forming entirely within the connecting membrane, which has the same diameter as the old valves, they are just so much smaller; and, as this mode of subdivision is repeated again and again, there are always two individual diatoms having one old and one new valve, which latest formed valve is continually being replaced by another still newer. That the cell-contents may be at no time exposed to direct contact with the surrounding water, the connecting membrane is formed of two pieces, by additions next to the two valves; and, as one valve of the diatom individual is always somewhat smaller than the other, one of these sections of the connecting membrane is smaller than and slides within the other. In some cases, however, it would seem that the connecting membrane is made up of but one piece, instead of two, as described. On account of this gradual diminution in size which must

take place, we can readily understand how we shall be very likely to find diatoms growing together which are exactly alike, except that they vary in size. But instead of the smallest being the oldest, the largest were formed first, and, by the process of subdivision described, they have gradually diminished in dimension. And it would seem that there was a limit in each species beyond which the frustule did not diminish, but as soon as it was reached, then the stage had arrived when reproduction sets in in the manner to be presently described. Thus we see how one individual diatom may in a very short time populate a large lake or river; but all of these separate cells, which have now become separate individuals as well, will very closely resemble the first one from which they sprung. But circumstances may occur, while this rapid growth is going on, which may modify the characters of the diatom to such an extent that very marked variation may result. Thus, for example, if the original frustule existed at the head waters of a small stream, in perfectly fresh, running water, some of its descendants may be carried down into a lake where they may lodge along the shore, in still water, and thus become modified, or, they may pass on into a large river, to be there affected, or even carried down to its mouth, and there, where the salt and fresh waters mingle, be changed by that circumstance. So, of course, other circumstances, which will readily present themselves to the mind, will serve to form and perpetuate variation in the diatoms, until two frustules, descended from the same progenitor, by growing under different circumstances, will appear so unlike that they may be classed as separate species, or even as belonging to separate genera.

The time occupied in a single act of self-division in the diatoms has not been ascertained for all species, although it has been lately noted for a few; "but supposing it to be completed in twenty-four hours, we should have, as the progeny of a single frustule, the amazing number of one thousand millions in a single month,—a circumstance which will, in some degree, explain the sudden, or, at least, rapid appearance of vast numbers of these organisms in localities where they were but a short time previously either unrecognized, or only sparingly diffused."

In all cases, however, the two newly formed frustules do not entirely separate from each other, for, after subdivision has taken place, they remain united, so that in time others will be added, and eventually a long

ribbon-like assemblage of individuals result. The genera *Fragilaria*, *Himantidium*, and *Rhabdonema*, are examples of such a mode of growth when the valves are oblong, and *Melosira* when they are circular. Then, again, the separation may be partial, so that the frustules remaining united by the alternate corners are attached to each other, and a zigzag chain is formed. *Diatoma* and *Grammatophora* are examples of this. If the frustules are not possessed of quite parallel sides, but if they, on the contrary, approach each other at one end, and then remain united after subdivision has taken place, a fan-shaped arrangement will result, as is seen in *Lichmaphora*; or, if subdivision continues, a spiral will be formed as in *Meridion*. Those forms which do not float about freely in the water in which they live and grow, are attached to submerged objects by either a small gelatinous cushion, a long single or branching stalk, pedicle, or "stipes," as it is called. And there are forms, as *Schizonema*, which are of a naviculoid form, but which secrete around themselves a membranous tube within which the process of subdivision goes on, and up and down the cavity of which the little boats sail with extreme activity. Thus, from this simple process of subdivision, as described, various forms may result, and many individuals be formed which shall have their number still further increased by the process of reproduction to be next described.

PART FOURTH.

Reproduction of the Diatomaceæ.

We have seen the manner in which the diatomaceæ increase in dimensions, or grow, and observed that it is essentially the same process as that which takes place in larger and apparently more complex organisms, both animal and vegetable. That is to say, we have found that in the case of the diatomaceæ it becomes very difficult, if not impossible, to distinguish the results of growth from the results of reproduction. And although at first sight this may appear a very remarkable fact, yet it ceases to be so if we remember that really physiology teaches us that reproduction is merely a form of modified growth, resulting after the casting off from the parent's body of one or more masses of matter which possess in themselves the power of assimilation of food, and its appropriation for the building up and elaboration of new tissues. Those genera

of diatomaceæ which occur normally, or, we should say, most commonly, attached in some manner, as by a cushion, pedicle, stipes, or the surface of the valve or connecting membrane, or otherwise, to submerged objects, would never become very widely distributed through the agency of self-fission alone, as it has been described, and the consequence would be that they would be confined to certain localities were there not some other mode of increase or reproduction. To a certain extent, this distribution is provided for by the curious movements of the individual which we have just treated of, and which we have seen are quite lively in some species. But it is still more perfectly insured by the process of reproduction in which a new individual is developed from a parent. It is in the form of spores or seeds that most plants (or, at least, the larger ones with which we are acquainted) are enabled to endure the severe frosts of the winter months; and the same is likely to be the case with the diatomaceæ, although it is true that some species are to be found living and swimming actively about beneath the frozen surface of ponds and streams. And, although they be caught within the mass of solid ice, yet their vitality does not seem to be materially compromised, for, on thawing the ice they again move about in a lively manner in the water formed. Very little investigation has been carried on in the direction of the reproduction of the diatomaceæ, or, rather, we should say, that little has been published in this connection, so that we have few authorities to draw upon to enlighten us on this point in the economy of our little friends. From what little has been observed and recorded by a few investigators, it would seem that the diatomaceæ reproduce after a manner very similar to that which has been found to take place in the *Protophyta*, or simple unicellular plants; and this fact has been brought forward as an argument in favor of the vegetable nature of the organisms of which we are treating.

The first instance in which the process of reproduction was observed and published was by Mr. Thwaites, in *Epithemia*, a genus which is almost always found in the living state, attached to submerged plants, as mosses and the like. He found it to be essentially the same as the mode of conjugation, as it had been called, known to take place in several algæ or water plants of simple organization. He describes it in the following manner: "The process of conjugation consists in the union of the endo-

chrome of two approximated fronds [using this term instead of frustule, to indicate the perfect individual], this mixed endochrome developing around itself a proper membrane, and thus becoming converted into the sporangium." The sporangium is what may be called the seed vessel, as, although it does not contain seeds, in the ordinary acceptation of that term, yet from it proceed the new individuals who are to perpetuate the species. "In a very early stage of the process, the conjugated frustules have their concave surfaces [it must be remembered that we are speaking of *Epithemia*, whose outline is somewhat bow-shaped, having convex and concave surfaces] in nearly close opposition; and, it may be observed, that from each of these surfaces two protuberances arise, which meet two similar ones in the opposite frustule; these protuberances indicate the future channels of communication by which the endochrome of the two frustules becomes united, as well as the spot where is subsequently developed the double sporangium, or, rather, the two sporangia. The mixed endochrome occurs at first as two irregular masses between the connected (conjugating) frustules; but these masses shortly become covered with a smooth cylindrical membrane, the young sporangia, which gradually increase in length, retaining nearly a cylindrical form until they far exceed in dimensions the parent frustules, and, at length, when mature, become, like them, transversely striated upon the surface. Around the whole structure a considerable quantity of mucus has during this time been developed, by which the empty frustules are held attached to the sporangia." Thus we see that, whether any two particular frustules are drawn towards each other or not (which we do not know), yet two contiguous individuals pour out their respective contents, which, melting together, are thus fused into a mass, around which is formed one or two new siliceous coats exactly alike in structure, but only differing in size, being larger than those which enclose the parent frustules. Enveloping these sporangia, or large cases from which the new individuals shall be evolved, is thrown a protecting, or, perhaps, nutritive globular mass of transparent mucous material. In different genera, slight variations are met with in the method of conjugation, as described. Thus, in some species of *Gomphonema*, which grows attached to the end of branching stalks or stipes, very much after the manner of the leaves on the ends of the twigs of a tree, the sporangia lie in a direction parallel to the empty parent frustules

by which they have been generated, instead of across them, as is the case in *Epithemia*. Although in many cases the frustules, which are about to conjugate and form sporangia, split into two separate parts, so that their contents may freely coalesce, we find that there are examples where the valves only split apart at one end to a slight extent, but enough to serve for the escape of the endochrome. Instead, also, of the pair of conjugated frustules, producing between them two sporangia, they may develop but a single one. The *Melosiræ* and *Biddulphiæ* (the former looking like a string of pill-boxes attached together by their tops and bottoms; and the latter being somewhat like a number of wool-sacks united at the corners into a chain), Mr. Thwaites remarks, "would seem in their development of sporangia to offer an exception to most diatomaceæ; for, in those genera, no *evident* conjugation has been seen. However, something analogous to it must take place; for, excepting the mixture of endochromes of two cells, the phenomena are of precisely similar character. Thus, instead of the conjugation of two frustules, a change takes place in the endochrome of a single frustule; that is, a disturbance of its previous arrangement, a moving towards the centre of the frustule, and a rapid increase in its quantity; subsequently to this it becomes a sporangium. In a single cell, therefore, a process, physiologically precisely similar to that occurring between two conjugating cells, takes place; and it is not difficult to believe, taking into view the secondary character of cell-membrane, that the two kinds of endochrome may be developed at the opposite ends of one frustule as easily as in two contiguous frustules, and give rise to the same phenomena as ordinary conjugation." In such genera as have their siliceous frustules enclosed within membranous tubes, as *Schizonema*, conjugation seems to take place both without and within the tube, but oftenest upon the outside. As has been remarked, "one reason for the paucity of observations on this process in the diatomaceæ is no doubt to be found in the changes which usually take place in the condition of these organisms at this period of their existence. During conjugation the process of self-division is arrested, the general mucus envelope or stratum, produced during self-division, is dissolved, and the conjugating pair of frustules become detached from the original mass; they are thus more readily borne away and dispersed by the surrounding currents, or the movements of worms and insects, and their

detection becomes in consequence more casual and difficult." The modes of conjugation have been reduced to four classes, thus: 1st. We have two parent frustules and two sporangia, as the result of their conjugation. This mode has been seen to take place in the genera *Epithemia, Cocconema, Gomphonema, Encyonema*, and *Colletonema*. 2d. From the conjugation of two parent frustules we have formed a single sporangium. This mode has been only seen to take place in *Himantidium*, but most likely will be found hereafter to be natural in allied forms. 3d. The valves of a single frustule separate, the contents set free, rapidly increase in bulk, and finally become condensed into a single sporangium. This has been seen in *Cocconeis, Cyclotella, Melosira, Orthosira*, and *Schizonema*. 4th. From a single frustule, as in the last mode, two sporangia are produced in the process of conjugation. This takes place in *Achnanthidium* and *Rhabdonema*. Thus far has observation gone; but no one seems to have traced the further history of the sporangium. For we find no record of the undoubted production of gonidia, as they are called, or seeds possessed of motion, from the contents of the sporangium. In fact, we have no proof that such contents are developed into spores, still or motile. It is true that Rabenhorst, a German observer, has figured and described what he supposes to be the development of gonidia or motile spores from the contents of a sporangium in a filament of *Melosira varians*, an extremely common species found growing in fresh water in all quarters of the globe. It would seem strange, therefore, that others have not seen the same thing; and later observers have doubted his record for this reason alone, apparently, that they have not chanced to see it. However, Smith, one of the best of the English authorities on this subject, says,—"On the whole, the facts at present within our knowledge seem fully to warrant the conclusions that the conjugated state of the diatomaceæ is the first step in the reproduction process of these organisms; and that the sporangial products of this condition become the parents of numerous young frustules destined to renew the cycle of phenomena which accompanies the life and growth of the species from which the sporangia have thence originated." It is very likely that the contents of the sporangium are converted into spores or gonidia, as Rabenhorst has stated, and that after escaping and moving rapidly about, and thus aiding in distributing the species, these gonidia

develop around themselves siliceous shells or skeletons, and become diatoms of the normal dimensions of the species from and by which the sporangium was produced. On the other hand, the sporangia may constitute the "resting" state, such as is known to occur in several simple forms of life, in which the species encounters the severity of the winter only to reproduce the species in the spring. In this case, examination of localities, known to produce certain species during the summer, should, during the winter months, be searched when most likely there would be found abundance of sporangial forms. I am not aware that any such investigations have been as yet made; and the difficulties surrounding the study of these organisms is so great that but few have the patience requisite for such work. Hence we find that most of the papers relating to the diatomaceæ, which have been published, are by persons who delight in the naming of "new species," and have not cared to spend the time necessary to determine whether they be but transition forms, sporangia, or true species.

Although, then, as has been said, the whole life-history of the diatomaceous sporangium has not been established, yet we know enough to convince us, as Prof. Smith says, that "the ordinary diatomaceous frustule seems to owe its production to the protoplasmic contents of the sporangial frustule formed by the process of conjugation. These sporangia, like the seeds of higher plants, often remain for a long period dormant, and are borne about by currents, or become imbedded in the mud of the waters in which they have been produced, until the circumstances necessary to their development concur to call them into activity. At such times, their siliceous epiderms open to permit the escape of the contained endochrome, which is resolved into a myriad of embryonic frustules; these either remain free, or surround themselves with mucus, forming a pellicle or stratum, and, in a definite but unascertained period, reach the mature form of the ordinary frustule." Prof. Smith has made observations which appear to establish this fact of the formation of motile spores, which he details in the following words: "In the gathering of *Cocconema Cistula*, made in April, 1852, which contained numerous instances of the conjugating process, I observed the frequent occurrence of cysts enclosing minute bodies, variable in their number and size, and many of which had the outline and markings of the surrounding forms,

and were obviously young frustules of the *Cocconema*. It would appear that production of the young frustules is preceded by the separation and throwing off of the siliceous valves of the sporangium, and the constriction or enlargement of its primordial utricle, according to the number of young frustules originating in its protoplasmic contents. In this gathering, forms of every size, intermediate between the minutest frustule in the cyst and the ordinary frustules engaged in the conjugating, were easily to be detected; and the conclusion was inevitable that the cysts and their contents were sporangia of the species with which they were associated, and indicated the several stages of the reproductive process." Although this observation seems to confirm the supposition that the contents of the sporangium must divide into a number of small frustules similar to the parents from which the sporangium sprung, yet further study is necessary before we can consider this fact established; and such study can only be carried out by those who are willing to keep alive for hours, days, or even weeks, such forms as they may meet with, and spend hours at a time at the microscope, watching any change that may take place in them.

Thus do we see the diatomaceous frustule becoming gradually smaller and smaller, through the carrying on of the process of self-division, and its return to the normal dimensions through conjugation, or the formation of gigantic sporangia, whose cell-contents shall return by subdivision, and the genesis of motile spores to the size of the parent frustules. A perfect cycle of changes would seem to be thus kept up, such as is by no means uncommon in the life-history of many simple plants grouped under the head Protophyta. And we are at the same time reminded, when witnessing these changes and transformations, of the equally wonderful metamorphoses, well known to naturalists, to take place in the jelly-fish and hydroids of our coast, or those of the insect world, and which we see going on day by day around us. The egg becomes a grub, the grub a caterpillar, which, in turn, changes into the quiescent chrysalis, in which commonly the winter is passed, only to burst forth, as soon as the revivifying rays of the spring sun warm it into being, as the gorgeously tinted and active butterfly, the parent of innumerable eggs, which shall in turn produce another generation of grubs.

PART FIFTH.

Modes of Occurrence, and Uses to Man of the Diatomaceæ.

And now it will be desirable to say something with regard to the various modes of occurrence of the diatomaceæ, specifying the particular habitats or kinds of situations or water (salt, fresh, or brackish), for the use of such as may wish to know more concerning these beautiful atomies than can be told within the limits of a short sketch like the present. Thereafter it will be well to say something of the importance to the geologist of knowing the life-history of the diatomaceæ, and, finally, their uses to man in the arts and otherwise, as they occur in mass in various parts of the world. And in this connection we are reminded of the words of the poet, who says,—

> Naught so vile that on this earth doth live,
> But to the earth some special good doth give;

for we find that the diatomaceæ have in past ages played, and, in truth, still are playing, a most important part in the grand drama of nature; and their minute dimensions is no excuse for the neglect to which they have been subjected by scientific and capable observers.

Diatomaceæ are to be looked for in both fresh and salt water, as well as in that which can be included under neither of these heads, the brackish water of seaside marshes, where the springs of to-day are overflowed by the rising tide of to-morrow. In general, the piece of water in which they are looked for must be permanent, for authors tell us that it is useless to expect to find them in the transient pools left by the rain. This is, however, not strictly the case, for, on one occasion, I found diatoms in a pool formed by the drainings of a stable-yard, and even little collections of water only two or three days old have occasionally yielded forms when carefully searched, but in such cases they were only few and minute. Prof. Gregory found them in moist earth about the roots of plants, and others have collected them from between the branches of mosses which clustered upon tree barks or house-tops. Even the dust which has fallen upon the sails and decks of vessels, far out at sea, have been found to contain them, by the German microscopist, Ehrenberg, who therefrom has deduced certain supposed facts with regard to atmospheric

currents. Upon these foundations Maury has formed theories which, however true they may be in themselves, are not borne out by later researches, for the forms which Ehrenberg supposed to be peculiar to certain quarters of the globe have been found to be almost universally distributed; and, therefore, any deductions, which may have been established in consequence of their appearance upon a ship, do not prove that they were brought from the spot where they were first seen. In fact, the diatomaceæ would seem to be more widely distributed than any other group of organisms, animal or vegetable; and the student of them need never be at a loss for specimens to examine. The pool by the road-side, the mud of the river bank, the moss upon the house-top, the earth beneath his feet, or the air above his head, may be searched, and will all of them yield him material for observation, wonder, and delight. In the living state, and, as often found, floating upon the surface of the water of a pond or slowly running river, swamp, or ditch, the diatoms present themselves as a flocculent collection of more or less dark rust-colored matter, coherent in stringy masses, when such genera as *Melosira, Fragilaria,* or *Himantidium* occur, or consisting of particles readily dispersed and scattered when *Navicula, Pinnularia,* or other so-called free genera exist. The color of such a mass may vary from a golden orange to a dark brown, according to the thickness of the stratum or particular species present, or, it may take on a greenish tinge at certain seasons, which is supposed to indicate a change in the character of the endochrome having some connection with the process of reproduction. At times, I have found that bright green masses of floating confervæ,—which are filamentous water-plants found in all waters, both fresh and salt,—will yield beautiful specimens of diatoms, which are entangled among their branches, or grow adherent to them. But in most of such cases the species belong to the group of adherent forms, and for those we are to look to submerged plants, sticks, metal, and stones, and there they appear as a brownish or fawn-colored mass, either closely adherent, or with its free ends floating freely in the water, as delicate threads, borne hither and thither by the changes of the current. A sprig of some submerged plant, bearing a cluster of some such genus as *Himantidium, Fragilaria,* or *Tabellaria,* presents a beautiful object, as the fine hair-like filaments spread out on all sides, or bend with the motion of the

containing water. A very little practice will enable the searcher after diatoms to distinguish them, or to choose localities likely to yield them. I have found that, if the adherent mud on the submerged wood-work of a bridge or pier be scraped off and transferred to a bottle with some water, and, when brought home, be placed in a saucer or plate, covered with the water and exposed to the diffused sunlight which comes in at a south window, many very beautiful forms may be procured in sufficient quantity for observation; and, besides, in such saucers the diatoms may be kept and grown for a length of time, and many points in their economy studied with facility. Thus they may be watched through the process of growth by subdivision and conjugation, and the changes which they then undergo observed without being under the necessity of making several visits to their native localities to make collections. The dead skeletons of many rare species are to be found in the muds of our tidal rivers and harbors, that from some of our southern streams especially, where the summer season of vigorous growth lasts longer than with us, having yielded forms not otherwise procurable. All algæ, as the water-plants which do not bear apparent flowers are called, both marine and fresh water, bear upon their fronds diatoms in greater or less numbers; and the results of dredgings in deep water will provide the student with ample material for many an hour's amusement and instruction. The various methods to be employed, in preparing clean or mixed gatherings of diatomaceæ, can for the most part only be learned from experience, as the books tell us little on this subject. Some general directions, however, on this point will be appropriate to this sketch, and will be given hereafter. As the diatomaceæ live, grow, and multiply, thus floating freely on the surface, along the bottom, or through the mass of the water, or wave in tiny filaments from other objects, they must die; and the most perishable part of their bodies, namely, the cell-contents, will be dissolved in the water or dissipated in gases, to return and again build up new individuals at some future time. But their less perishable portions, their siliceous skeletons, will fall to the bottom of the pond, lake, ocean, or river, and there collect. Their remains will also be found in the stomachs of such animals as are vegetable feeders, as are most of the mollusca, like the oyster, the clam, and the water snails, as well as the crustacea,—lobsters, crabs, and the like. So, like-

wise, the alimentary canals of sea urchins and sea cucumbers, as they are commonly called, but whose correct and scientific, although, perhaps, at first more incomprehensible names are echinoderms and holothurians, as well as many fish and countless smaller creatures inhabiting the waters, both fresh and salt, will be found to contain the skeletons of diatoms which they take in directly as food, or indirectly when browsing upon the algæ and other examples of aquatic vegetation. So the examination of the half-digested food, from the stomachs of these creatures, will often repay the trouble of preparing it for the microscope. And here is an appropriate opportunity of saying something with regard to that remarkable and important substance which goes by the name of guano, and which has proved to be an almost inexhaustible storehouse for beautiful forms of diatomaceæ. Very generally this substance is supposed to be the excrements of birds, which has accumulated in large quantities during the lapse of many years upon the rocky islands in the Pacific ocean and elsewhere, in latitudes where little or no rain falls to wash out the organic matter. This substance has been used by the inhabitants of the coast of South America from time immemorial as a manure; and, since it was introduced into Europe by Humboldt, in 1804, it has been largely exported to that country and this, to supply the exhaustion of our fields by the continuous crops necessitated by our always increasing population.

Some years since, the attention of the writer of this sketch was called to the subject of guano, when engaged as an analytical chemist in examining fertilizers of different kinds; and thereafter, when studying the diatomaceæ and the application of a knowledge of them to geology, he pushed his investigations still further, and at last came to the conclusion that the popular prevalent notion with regard to the origin of guano was erroneous. His ideas on the subject he embodied in a communication made to the Essex Institute of Salem, Mass., on the 4th of January, 1869, an abstract of which will be found in the Bulletin of the Association, vol. I, p. 11. Subsequently, with the Hon. E. G. Squier and Dr. A. Habel, who had visited the celebrated Chincha islands, and there observed some facts which confirmed the present writer's notions with regard to it, he again brought the subject prominently before the public at a meeting of the New York Lyceum of Natural History, held May 1,

1871. *(Proceedings Lyc. Nat. Hist. N. Y.*, vol. I, p. 224.) Therein it is shown that guano is most likely not the excrements of birds or other similar animals, deposited upon the islands and main land after their upheaval, but that it is the result of the accumulation of the bodies of animals and plants, for the most part minute, the diatomaceæ making up a large part of the mass, and subsequently upheaved from the bottom of the ocean by volcanic agency, which is known to be very active and pretty constant in that part of the world. In this way guano has become a storehouse of many otherwise rare and beautiful forms of diatomaceæ, which can be procured from it by employing a proper process with chemicals to destroy and remove everything but the siliceous skeletons, which are then left in all their purity, so that their forms may be viewed by means of the microscope. The process for cleaning guano, so as to obtain the microscopic organisms contained in it, will be described hereafter.

In a semi-fossil condition, the diatomaceæ are to be found in all parts of the world, and very extensively within the state of New Hampshire in the form of what have been called lacustrine sedimentary deposits,—that is to say, collections of their dead skeletons formed at the bottom of lakes, and going commonly by the name of "marl," although true marl contains few, if any, diatoms, and is largely made up of the shells of mollusca, snails, and the like. The mode of formation of these deposits will be described hereafter.

Still more ancient, and, what may be with propriety termed truly fossil deposits of fresh-water diatomaceæ, are not found on this coast of the North American continent, but, in fact, appear to be confined to the Pacific states, where they cover vast tracts of country. Their mode of formation will be described when we come to treat of the application of a knowledge of the diatomaceæ to geology, in a subsequent part of this sketch. Thus extensive strata of diatomaceæ have accumulated and become fossilized, and constitute the "infusorial earths" of geologists and others, many of those on our Pacific coast, as has been said, being made up of the remains of fresh-water species which have lived, grown, died, and been laid up in countless millions in the beds of now extinct lakes; while, likewise, in California, as well as in Virginia and Maryland, in Peru, Japan, and Algeria, are found layers which are made up of the

skeletons of marine species. The city of Richmond, Va., rests upon such a stratum, which varies in thickness from twelve to twenty-five feet, and which extends to Fortress Monroe and over the Potomac river into Maryland, and all the way down on both sides of the Patuxent river in that state. The principal localities from which these deposits, fresh-water and salt-, have been obtained so far, will be mentioned in the directions for collecting, to be given hereafter.

Besides objects of great beauty and scientific interest, the uses to which the diatomaceæ have been put may be briefly summarized. It is to be hoped that the unlearned, whose attention has for the first time, perhaps, been called to them by this sketch, will feel that the elegance of their forms and the geometrical purity of their sculpture will recommend them sufficiently, without eliciting the question, which unfortunately has been propounded with reference to other scientific subjects, viz., What good are they? That they serve as food for numerous aquatic animals is plainly shown by the fact of their being found in their stomachs; but, if that were their only use, it could hardly be said that they were of value to man directly. Who would suppose that these little atomies, so seemingly insignificant, could serve as sustenance for the human race?—and yet such is the fact. In the bleak and almost barren parts of Lapland, during times of scarcity from failure of the crops, the infusorial deposits are turned to account, under the name of "*berg-mehl*" or mountain meal, to eke out the scanty supply of flour with which they are mixed before it is made up into bread and eaten. In some other parts of the world we find wild nations making a similar use of such "infusorial deposits;" but we can hardly say they serve as food, for although some authors have supposed that some of the organic matter they contain may be absorbed by the stomach or intestines, it is not likely that such is the case. It is much more probable that the earthy material serves to clog the stomach, and, by the mere act of distention, arrest for a time the pangs of hunger. Their siliceous character is opposed to their serving as food in the true acceptation of that word. In Samarancy and Java, under the name of "tanah," an earth of this kind, made up of the siliceous remains of diatomaceæ, is eaten. It is described as "generally solid, plastic, and sticky, and is rolled and dried in the shape of small sticks over a charcoal fire, and is

eaten as a delicacy." The natives of our western coast, as well as the inhabitants of some parts of South America, use an "infusorial earth" as a pigment to decorate their bodies. In guano, doubtless the diatomaceæ play a very important part, when that substance is employed as a fertilizer and spread upon our fields, for they then present the silica in an extremely minute state of division to the moisture of the soil and the air, which gains admittance thereto, either along with the water or on account of the porosity of the earth. It has been found that under these circumstances the silica is dissolved and absorbed by the plant that requires it, in whose tissues it is deposited to form a strong support to its framework. The cereals especially require a certain amount of silica, as is well known, for the strengthening of the stem which serves to elevate the seed where it gets the benefit of the sun and the air. So we find that all the grasses, as wheat, oats, sugar-cane, maize, grow best on a soil from which they can abstract sufficient silica for the purpose indicated. Instances have come to my knowledge where recent wet deposits of diatomaceæ, especially those containing organic matter, and mentioned above under the designation of lacustrine sedimentary, have proved of real value as fertilizers, when mixed with stable manure and used for cereals, but, of course, they would be objectionable if applied to root, fruit, or leaf crops.

Many deposits of diatomaceæ are called tripoli and polishing powders; and these names indicate that they are possessed of properties which peculiarly fit them for polishing hard surfaces, such as metal. The extremely minute state of division of the silica in the diatom-valves, and the readiness with which those valves are fractured and broken down into still smaller angular portions, are remarkable, and could hardly be imitated by any artificially prepared powder. It has been suggested that the vast diatomaceous deposits found in some parts of the world, as the strata occurring in Virginia and California, might be turned to account, as presenting silica in a fine state of division, so that it can readily be acted upon by the alkali, and the so-called "soluble glass" made therefrom. One manufacturer has experimented somewhat in this direction, but with what result is at present unknown.

It is, however, to the scientific student that the diatomaceæ are of the greatest interest and really of use, for they have proved valuable in

assisting him in the investigation of various subjects, as the matter of the conditions of existence of the simple cell, and, likewise, the former characters of certain strata in which they are found in vast numbers. The bearings of this latter subject will occupy our attention in Part Sixth.

PART SIXTH.

THE DIATOMACEÆ AND GEOLOGY.

The manner in which the diatomaceæ increase, both by true growth and reproduction, has been described in such detail that it is to be hoped that it is thoroughly understood. At the same time, it can be readily comprehended how, as they secrete, from its solution in the water in which they live, the siliceous material constituting their harder parts, and, as they die, this flinty matter must after a time form a deposit at the bottom of the lake or ocean which they inhabit. We are, then, prepared to take into consideration the formation of such deposits, both fresh and salt, and their connection with the science of geology.

The mode of formation of fresh-water deposits of diatomaceæ, as lacustrine sedimentary strata and as fluviatile fossil layers, has been fully described in a paper read by the present writer before the New York Lyceum of Natural History, Nov. 28, 1870, and published in the proceedings of that association, vol. I, p. 109; and the major part of that communication will be given here as embodying about all that is known on that subject, and detailing at the same time the author's ideas with regard to the enormous deposits of fresh-water diatomaceæ found spread over many parts of the western states of the North American continent.

We have seen how the diatomaceæ increase by subdivision, so that by this means alone they may multiply extremely rapidly, and a single individual, by means of its descendants, soon populates a large pond or lake. But while subdivision or true growth has been thus progressing, increase by generation or seeding may have taken place at the same time, and, from each individual in turn, several young may have been brought forth, which would multiply the rate of increase very materially, of course. It is true that the mode of seeding of these organisms is not thoroughly understood; but we know enough to say that it does occur, and very frequently, and that the number of new individuals thus formed is very great. At the same time, numerous individuals are dying, and,

as they do so, much of the organic matter of which they are composed is dissipated, but some of it, along with the hard siliceous valves and connecting membranes which constituted the skeletons of the diatoms, falls to the bottom of the pond, and forms a layer of greater or less thickness, according to the time during which it has been accumulating. If it be exposed now, by draining such a pond, it may appear as a brown or grey powdery mass, but, if it has rested beneath the the water sufficiently long, almost all of the organic matter will be removed, and the clean, white siliceous skeletons alone remain. In some localities,—and this I have found to be the case in the state of New Hampshire, perhaps from the peculiar topography of the spots where these masses of the accumulated dead shells of diatoms are found,—these organisms grow in bogs of no very great superficial extent, but which, from their occurring in hollows between hills, are often quite deep. Under such circumstances, as I should judge from the character of a deposit I examined at Bowkerville in Cheshire county, the organic matter might for the most part decay out of a layer of considerable thickness, and nothing be left but a mass of finely divided siliceous material of a character well fitted for use as a polishing powder, or for other purposes to which this substance has been applied.

Such are the results, then, of this rapid growth of the diatomaceæ in ponds, lakes, marshes, and rivers; and, as the first examples of such deposits which I examined were found beneath layers of peat, I gave to them the name "sub-peat" deposits, and under that designation they have been generally known. After a time, however, specimens came into my hands which were procured from the bottoms of existing ponds, and these, besides consisting for the most part of little else than silica, and being of an almost pure white color, had no peat overlying them. Hence, of course, I saw the inapplicability of the term "sub-peat" to such deposits, and for them I have coined a new name, viz., lacustrine sedimentary, which I consider more appropriate, and at the same time indicating their usual origin, and including all deposits of fresh-water diatomaceous remains, with the exception of certain peculiar layers to be hereafter described. Of course the sub-peat then become a variety of these. Deposits of this character are extremely common in this country, as well as elsewhere, and it will be at once seen that, although

any one of them might be of great thickness, yet it does not necessarily follow that it had been forming for any great number of years; and geologists and others are not warranted, from observance of this one fact of thickness, in supposing that a great length of time has intervened during its deposition. Thus, some years since, I examined one of these lacustrine sedimentary deposits, at a spot near the town of East Stoughton in Massachusetts, which was fully twelve feet thick, but only covered a few feet of surface, which circumstance was due to the occurrence of a dam across the course of a stream, which arrested its progress and formed a small, deep pond, into which all of the diatomaceæ, which grew for some considerable distance up stream, drained, and, dying, accumulated as a light grey-colored powder. I have received specimens of similar material from many points in this country, so that about one hundred have been examined. The state of New Hampshire has supplied quite a number, and they will be hereafter described, and the forms detected in them illustrated.

The first recorded discovery of a lacustrine sedimentary deposit of diatomaceæ in this country is found in *Silliman's Journal*, 1839, vol. xxv, p. 118, in an article "On Fossil Infusoria discovered in Peat-earth at West Point, N. Y., with some notices of American species of Diatomæ. By J. W. Bailey." Of this I have a small portion given me by Prof. Bailey himself, and, on examination, it is found to have the general characteristics of these deposits; that is to say, it is of a grey color, light in density and very friable, and is made up of the siliceous skeletons of such species of diatomaceæ as grow in small fresh-water lakes, ponds, and marshes. In fact, Prof. Bailey says that this deposit, which was "eight or ten inches thick, and probably several hundred square yards in extent," was discovered "about a foot below the surface of a small peat-bog immediately at the foot of the southern escarpment of the hill on which the celebrated Fort Putnam stands." He considers the remains present in this stratum to be "in a fossil state." And here, perhaps, it is desirable to say something with regard to the use of this term. Its origin would warrant its being applied to anything dug up out of the earth; and, as Mr. Page remarks in his *Handbook of Geological Terms*, "hence the earlier geologists spoke of *native fossils* or minerals, and *extraneous fossils*, or the bodies of plants and animals accidentally

buried in the earth." For myself, I am disposed to restrict the term fossil to the remains, more or less perfect, of organized beings dating anterior to the present epoch, if we can conscientiously speak of epochs at all where the progression and rate of change have been so gradual. Considered thus, then, these remains of diatomaceæ cannot be classed as fossils; and at once the geologist perceives that they are to be taken into account in a very different manner from what they have been hitherto. So much, then, for lacustrine sedimentary deposits of diatomaceæ; and I trust that I have made clear as to what they are, and how they are formed and forming. At the time I made his acquaintance, Prof. Bailey expressed an opinion that similar strata would be found beneath every bog and pond in the country. The clear scientific vision of my late friend is evidenced in the fact that this prediction was proved almost literally true. I have over one hundred such specimens, and am continually receiving others. Several I have already described, and others remain to be examined, and facts with regard to the geographical distribution and other points will be elucidated by such investigations,—so that I am always anxious to receive contributions from all sources. It is only desirable that all facts connected with their mode of occurrence, as to amount in thickness and extent, over- and underlying material, etc., be noted at the time of making the gathering.

We now come to consider deposits of an entirely different character from those just spoken of, but which yet are also made up almost entirely of the siliceous remains of fresh-water diatomaceæ. These are the so-called "infusorial" deposits found in such enormous quantity in our Pacific states. From time to time, during the last thirty years, specimens of these have come into the hands of naturalists, from collectors and otherwise, and also "in place" they are well known to settlers in the districts where they occur. As their true character has not been understood, they have received various appellations, as "magnesia," "porcelain clay," "white clay," "chalk," "siliceous marl," "microphytal earth," "tripoli," "rotten-stone," "pipe-clay" or simply "clay," "trachytal tufa," and "phytolitharian tuff," by Ehrenberg. These specimens are almost always white in color, or nearly so, although there are records of some strata occurring of various tints. None of these except the white ones have come under my observation, so I am not prepared to state that the

colored ones are diatomaceous. Besides, this material is of a somewhat hard, stony character, but porous withal, and light; as a general thing, also, it is readily broken, but not easily powdered, as are the lacustrine sedimentary deposits. On account of this hardness there is found to be considerable difficulty in preparing these specimens for microscopical examination. After so preparing, by a method I have devised, to be described hereafter, and viewing with a sufficiently high magnifying lens, this substance is found to be made up entirely of the siliceous remains of fresh-water diatomaceæ which have been matted together in the remarkable manner described. The species of diatomaceæ present, however, are found to be very different in character from those to be seen in the other class of recently formed deposits. Thus, while the genera most commonly represented in and making up the mass of the lacustrine sedimentary deposits are *Navicula, Pinnularia, Stauroneis, Synedra,* and similar elongated forms, the hard, white material is in general found to consist of myriads of examples of *Orthosira, Cyclotella,* and similar discoid forms. Although our knowledge of the forms of these minute organisms, peculiar to different kinds of collections of water, is rather imperfect, yet we know that the naviculæform genera spoken of above are found in small lakes, while in the larger pieces of water are to be seen growing more particularly the discoid genera like *Cyclotella.* From this fact alone, then, we should be prepared to assume that the waters, in which the organisms whose remains make up these deposits grew at one time, covered large tracts of country. And our surmises on this point are confirmed by the reports of explorers who have passed over this section of country, that is to say, on both sides of the Sierra Nevada Mountains, from Puget's sound to the southernmost border of California, for they tell us that these deposits extend over a considerable portion of the Pacific states.

I have examined many specimens from this district, and, on account of the mode of occurrence of this material, being capped by lava, basalt, or some volcanically-erupted rock, I have designated them sub-plutonic. The first specimens of such sub-plutonic deposits of diatomaceæ, which were put into the hands of scientists, were undoubtedly those brought home by Frémont, from his expeditions to the Rocky Mountains, in the year 1842, and to Oregon and North California, in the years 1843

and 1844. The discovery of these, as detailed in his report, gives a good idea of this portion of the country, and is as follows. It must be premised that, in that report, what is now known as the Des Chutes river, and which is one of the tributaries of the Columbia, is called "Fall river" *(Rivière aux Chutes);* so, also, he spells Klamath lake "Tlamatt." Speaking of the tributaries of the Columbia river, he says (p. 200),—

These streams are characterized by the narrow and chasm-like valleys in which they run, generally sunk a thousand feet below the plain. At the verge of this plain they frequently commence in vertical precipices of basaltic rock, and which leave only casual places at which they can be entered by horses. The road across the country, which would otherwise be very good, is rendered impracticable for wagons by these streams. At such places the gun-carriage was unlimbered, and separately descended by hand. Continuing a few miles up the left bank of the river, we encamped early in an open bottom among the pines, a short distance below a lodge of Indians. Here, along the river bluffs present, escarpments seven or eight hundred feet in height, containing strata of a very fine porcelain clay, overlaid, at the height of about five hundred feet, by a massive stratum of basalt one hundred feet in thickness, which again is succeeded above by other strata of volcanic rocks. The clay strata are variously colored, some of them very nearly as white as chalk, and very fine grained. Specimens brought from there have been subjected to microscopical examination by Prof. Bailey, of West Point, and are considered by him to constitute one of the most remarkable deposits of fluviatile infusoria on record. While they abound in genera and species which are common in fresh water, but which rarely thrive where the water is brackish, not one decidedly marine form is to be found among them; and their fresh-water origin is therefore beyond a doubt. It is equally certain that they lived and died in the situation where they were found, as they could scarcely have been transported by running waters without an admixture of muddy particles, from which, however, they are remarkably free. Fossil infusoria of a fresh-water origin had been previously detected by Mr. Bailey in specimens brought by Mr. James D. Dana from the tertiary formation of Oregon. Most of the species in those specimens differed so much from those now living and known, that he was led to infer that they might belong to extinct species, and considered them also as affording proof of an alternation, in the formation from which they were obtained, of fresh- and salt-water deposits, which, common enough in Europe, had not hitherto been noticed in the United States. Coming evidently from a locality entirely different, our specimens show very few species in common with those brought by Mr. Dana, but bear a much closer resemblance to those inhabiting the north-eastern states. It is possible that they are from a more recent deposit; but the presence of a few remarkable forms, which are common to the two localities, renders it more probable that there is no great difference in their ages.

I have given in full all that Frémont says regarding this locality, as it presents us with the first discovery of strata of the remarkable character of which I am now treating, and is therefore of special interest. Bailey's report, contained in the same volume, merely mentions and figures the principal forms he detected.

The only other description of this locality and these remarkable deposits, fortunately, is a much more complete and scientific one. It is that of Dr. J. S. Newberry, as geologist of the expedition under Lieuts. R. S. Williamson and Henry L. Abbot, which explored the route for a railroad, from the Sacramento valley to the Columbia river, in 1855, and will be found in vol. vi of the Pacific Railroad Survey Report. Dr. Newberry gives a description of the geology of the Des Chutes basin, which is essentially as follows. It must be remembered that the Des Chutes and Fall river, mentioned above, are one and the same. The Des Chutes basin consists of a series of plateaus, having varying elevations from four thousand to twenty-two thousand feet above the level of the sea, separated by subordinate ranges of volcanic mountains. These plateaus are usually covered by a floor of trap, which extends in a smooth sheet from fifty to a hundred and fifty feet in thickness, unbroken except by and at the cañons of the various streams which, as a general thing, flow from the interior to the ocean at right angles to the coast line. Beneath this bed of trap is the whitish or light-colored material, consisting of the siliceous remains of diatomaceæ we are considering, sometimes occurring as a single bed only, sometimes as a series of beds locally intercalated with thin beds of trap. These infusorial strata, as they have been called, are cut in many places by the Des Chutes and its tributaries to the depth of more than a thousand feet, without exposing the basis on which they rest. They are usually quite horizontal, from a few lines to twenty feet in thickness, and very accurately stratified.

Psuc-see-que creek, one of the tributaries of the Des Chutes river, flows through a valley of a remarkable character, as its sides consist of several alternate strata of diatomaceous material and columnar trap or concrete. Near the base of this series of layers is a stratum, three feet in thickness, of brilliant white feldspathic pumice, so soft as to be easily crumbled in the fingers. Above, and lying upon this, is a line of dark

carbonaceous matter, less than a quarter of an inch in thickness, from which, up into another layer of pumice, projects the remains of the branches of some small plant which had apparently been killed by the overflow of the pumice. Lieut. Williamson gives a striking view of this locality, and speaks of it in the following terms:

This river cañon is very remarkable. Its sides vary from eight hundred to two thousand feet in height. The river has cut down its bed to this immense depth through successive strata of basalt, with occasionally a deposit of infusorial marl and volcanic tufa, which has sometimes hardened into a kind of conglomerate sandstone ten or twenty feet in thickness, and of a white, grey, or reddish color. We followed down this cañon for about five miles, when a rocky spur cut off all further progress, and compelled us to attempt the ascent. This with great difficulty we accomplished, and found ourselves on a plain thinly dotted with sage bushes and clumps of grass. We continued our course, and, after crossing the bed of a torrent of the rainy season, came to a very small stream, called Psuc-see-que by the Indians. It was sunk in a cañon about five hundred feet deep, cut through successive strata of basalt, infusorial marl, tufas, and conglomerate sandstone like that found in the Mpto-ly-as cañon (pp. 84, 85).

Another locality in which these remarkable deposits occur is on the Pitt river; and Lieut. Williamson's description gives such a good idea of the mode of their occurrence that I transcribe it, also, below:

The banks of the Pitt river, both above and below the mouth of Canoe creek, are partially formed by regularly stratified sedimentary deposits, the first seen since leaving the valley of the Sacramento. They appear on both sides of Pitt river at intervals for several miles, being in many places interrupted or covered by beds of trap. They are, perhaps, best exposed in the cañon formed by the passage of the river through "Stoneman's ridge," the most conspicuous of the lines of upheaval which form what is known as the lower cañon of Pitt river. They here exhibit a thickness of about fifty feet, but are considerably tilted up, and are covered by a thick bed of trap which has been poured out over them. They exhibit narrow and parallel lines of deposition, but are very homogeneous, and can hardly be said to form more than two distinct beds. Of these, the upper is white, resembling very pure kaolin, derived from the decomposition of crystalline feldspar. The lower bed is light brown or dirty white in color, and has a slightly gritty feel between the fingers. These strata rest upon a thick bed of rolled and rounded fragments of traps, porphyry, and basalt of all sizes, from masses of two and even three feet in diameter, to pebbles. They are generally as large as one's head, and great numbers are each a foot in diameter. The surface of this bed of boulders is perhaps twenty feet above the present surface of the stream; but it bears indubitable evidence of having at one time been covered by it, or, at least,

the stones composing it, so large and clear, have been rounded where they lie by a current or waves of water. The appearance presented by this bed of boulders is different from that of any of the beds of volcanic conglomerate which are so common in many parts of California and Oregon, or of the stratified conglomerates of the Sacramento valley, and it is undoubtedly of local origin. The trap which formed the greater part of the bank above is evidently of recent date, more recent than the infusorial marls, and the marls more recent than the conglomerate, and the conglomerate an accumulation of rolled stones and pebbles, which belongs to the present epoch. The trap which overlies the infusorial marls composes a large part of the walls of the cañon at this point, where it has been cut away by the stream, and forms nearly perpendicular faces of several hundred feet in height. The soft nature of the underlying strata has, however, very much assisted in its removal (p. 33).

There are several localities besides those mentioned at which this,—what I have chosen to designate "sub-plutonic,"—material is found, as at Klamath lake, on the northern border of California, and elsewhere all through the Pacific states. From these I have received gatherings, and have thus been enabled to examine, by means of the microscope, specimens from many points in what was once this chain of enormous fresh-water inland seas,—for such they deserve to be styled. For as the microscope reveals the fact, the organisms, whose stony remains constitute the mass of these deposits, were inhabitants of collections of fresh water which existed at some past period as large lakes; and a careful geographical examination of the country enables us even to indicate, to a certain extent, the situations once occupied by these now extinct seas, which at times varied in superficial dimensions, and certainly were in some cases drained, overflowed by lava, and renewed and replenished with living organisms as many as seven times.

And now that we understand how it is that lacustrine sedimentary deposits are formed by the accumulation of the dead shells of diatomaceæ, we can comprehend the manner in which these sub-plutonic strata have been laid down. If we look at the map of the western coast of the North American continent, we see that there are three great chains of mountains, about parallel to each other and the coast line, and thus enclosing between their peaks two long and wide valleys. The Rocky Mountains are the first of these chains, and they at one time formed the coast of this continent. Slowly and gradually, however, there appeared a line of islands at a distance from the coast, whose

material was volcanic, and, as these islands rose higher and higher, the space between them and the coast cliffs also rose until it became dry land. Soon rain fell and accumulated in this valley so formed, and lakes and rivers appeared. In these, diatomaceæ appeared, thrived, grew, reproduced, and multiplied; lacustrine sedimentary deposits were thrown down. Now came a time when the volcanic cones, which constituted the peaks of the range of mountains nearest to the coast, burst forth with fire and lava; and, probably at the same time, earthquakes took place which drained many of the lakes and changed the courses of rivers. Into the lake basins the lava was poured, with its heat evaporating the moisture, and consolidating the diatomaceous material into a stony mass, from which all organic matter was burned out. A period of rest succeeded. Diatoms again appeared and accumulated, to be again overlaid by lava; and so on the same thing may have again and again taken place. In this way the enormous deposits of sub-plutonic diatomaceæ were formed; and in the cracks, made in the rock by volcanic agency, the rivers wended their way, and made the gates we now are in the habit of calling cañons.

But in the ocean diatomaceæ also occur, and in large quantities. When they die there, their siliceous remains must accumulate at the bottom of the water, and occur as deposits. It is in the black mud of our quiet bays and harbors that we must look for the greatest accumulation of these remains; and rivers are carrying them down to their mouths, where often they are piled up in such masses as to form bars. The mud of the river Thames in England yielded to Mr. Roper a large number of diatomaceous remains. Ehrenberg examined the mud of the Elbe in Germany, and found these minute shells to make up from one quarter to one third of the whole mass. He calculated that at Pillau there are annually deposited from the water from seven thousand two hundred to fourteen thousand cubic metres of these minute shells, which in the course of a century would give a deposit of from seven hundred and twenty thousand to one million four hundred thousand cubic metres of deposit, which might be hardened into a stony mass. That such hardening has taken place is evidenced by the occurrence of the vast strata of marine forms found in Virginia and Maryland, on the Atlantic side of North America, and in California on the Pacific coast.

This material is often almost white, but more commonly is tinted slightly yellowish or salmon-colored. It makes up the most part of the material of the coast range of mountains in California, and has also been found in Peru, Japan, Algeria, Spain, and the West India islands. In California, in the almost rainless districts, it is used for building, but generally is too friable for that purpose. The forms occurring in it are for the most part discoid, with a few triangular ones, and, when prepared and examined by means of the microscope, present one of the most beautiful objects which can be so viewed.

Something has been said with regard to the origin of the substance known as guano, and which has been so extensively used as a fertilizer;—but to the agricultural fraternity anything connected with this material must prove of interest, so it is thought best to enter more fully into the consideration of this subject on account of its important bearings, its value to geologists, and its general attraction, evinced by the manner in which the publications of the present writer thereon have been copied and circulated by the periodical press.

On May 1, 1871, a discussion took place at the Lyceum of Natural History, New York, on the subject of guano, when the Hon. E. G. Squier exhibited a map of the Guanape islands of Peru, where guano is found, drawings of a wooden idol and other objects discovered in the guano, and photographs showing that that substance is distinctly stratified, and not thrown down in the shape of a confused mass, as would be the case if it were, as is usually supposed, merely the excrement of birds and other animals deposited on rocky islands, in localities where little or no rain falls to wash out its soluble and valuable constituents.

Dr. A. Habel, who had visited the Chincha islands for the purpose of studying the mode of occurrence of the guano (or, as he prefers to write it, in consonance with the mode of its pronunciation, "whuano"), made an extended communication showing that the outer and uppermost portion of this substance does consist of the droppings of various species of sea-birds and mammals, mixed with the feathers and eggs of birds, and bones. This layer does not at all show signs of stratification, and is of a reddish brown color. Below this is the guano proper, which is of a different structure, and distinctly stratified. He says that "this stratification is so marked that even a superficial examination must convince

every unprejudiced person that it is the product of sedimentary formation. It is made up of alternate white and yellow strata, varying in shade and thickness. All of these strata exhibit distinctly their inclination or dip, which varies not only on the separate islands, but in different parts of the same island. On the middle island, for example, the inclination or dip of the strata in one part of it does not amount to more than five degrees, while in another part it is eight degrees, and in a third, close to the first, fifteen degrees." In one place strata, running south-west and north-east, and dipping twenty degrees, rested unconformably on others running north and south, and dipping only four degrees. In all of the strata are imbedded stones of various sizes and weight up to fifteen pounds, as well as eggs and bones. Another proof that the guano has been deposited beneath the ocean is seen in the various strata of sea sand underlying it, and which are also stratified, and dip in one direction or the other.

The present writer said that he first made his hypothesis public, with regard to guano having been deposited beneath the water of the ocean, in 1868, at a meeting of the American Microscopical Society. In January, 1869, he entered more fully into a discussion of the subject before the Essex Institute, at Salem, Mass. He said,—

I have been for the last fifteen years or more studying the so-called "infusorial deposits" of marine origin. Among the specimens thus examined are some of the rocks or shales making up the great mass of the mountains of the coast range, which extend down the Pacific shore from Washington territory to the borders of Lower California, and even perhaps down as far as the southernmost extremity of that peninsula. These shales are usually of a light cream color, and mainly consist of the siliceous skeletons of diatomaceæ and polycystina, the former being commonly considered as plants, the latter as animals. These are of extremely minute size, and often require for their study the use of the highest magnifying powers. Many of them prove to be indistinguishable from forms living at the present day on the California coast. Exuding through, and often appearing at the upper portion of these rocks, to which situation they have evidently been driven by heat, are found the petroleum, bitumen, and asphalt of California. Hence the state survey has conferred upon these strata the name of bituminous shales. Along the Pacific coast, and lying parallel to it, are islands often bearing upon their summits deposits of guano, of more or less commercial value. In many cases the quantity has been small and soon removed; but I am informed that there are deposits of this material in that quarter of the globe still unworked. At the same time, it must be remembered that the whole Pacific coast, of

both North and South America, is in an almost continual state of motion, and gradual but constant upheaval, caused, doubtless, by the action of internal chemical changes, which make themselves markedly evident in the volcanic vents found all along the mountains constituting the Cascades and Sierra Nevadas of North, and the Andes of South America. There have been identified at least three former lines of rise of coast, and still another is seen presenting its peaks in the islands, which will, at some future day, be united in such a manner as to constitute another coast range of mountains.

If, now, we consider the bearing of these facts on the origin of the substance known as guano, we find the following points worthy of note. Guano may be divided into two great groups, the ammoniacal and the phosphatic; but it is of the first mentioned, only, that I desire to treat at the present time, and to which I wish to apply my deductions. Guano is usually considered as the excrement of sea-fowl, and which has accumulated during a long period of time,—so long, that attempts have been made to calculate its age from its thickness. Thus Humboldt, who first made this substance known to the Eastern hemisphere in 1804, states, that on the Chincha islands it has a depth of fifty to sixty feet, and that the accumulation of the preceding three hundred years has formed only a few lines of this thickness. The facts brought forward by Mr. Squier show how difficult it is to arrive at any certain knowledge on this point, and, in fact, show that we have no means of ascertaining the age of the guano deposits, even if we accept the theory of their origin from the source usually ascribed to them. We find that guano is not confined to islands only, but occurs in large quantities on the contiguous headlands; and many ravines, extending into the interior of the country, contain guano in smaller and larger quantities. Thus, the ravines of Lolo, Culata, Sacramento, Animas, Morillo, Guajes, Colorado, Chucumata, and Pica are reported to contain pure guano deposits, covered by a thick coating of sand. Neither is it found in rainless districts only, for, as I have said, it is found on the islands off the California coast, which are by no means rainless; and Mr. W. H. Dall informs me that it occurs on the Aleutian islands, where the air is almost always saturated with moisture, and heavy rains fall during a large part of the year. With regard to the upheaval of such coasts along which guano occurs, it is well known, from Darwin's investigations, that the whole Pacific coast of South America is in constant motion and upheaval, and that on the main land near Lima, and on the adjoining island of San Lorenzo, Mr. Darwin found proofs that the ancient bed of the sea had been raised to the height of more than eighty feet above the water, within the human epoch, strata having been discovered at that altitude containing pieces of cotton thread and plaited rush, together with sea-weed and marine shells *(Lyell, Principles*, 1853, p. 502).

And Darwin says,—"I have convincing proofs that this part of the continent of South America has been elevated near the coast at least from three hundred to five hundred feet, and, in some parts, one thousand to thirteen hundred feet, since the epoch of existing shells." Other proofs of this fact are not wanting, but these are sufficient for me to quote at the present time.

When the portions of guano, which are insoluble in water and acids, are examined

by means of the microscope, they are found to be made up of the skeletons of diatomaceæ, polycystina, and sponges, invariably of marine origin, and sometimes identical with those living in the adjoining ocean, and fossilized in the adjacent infusorial strata. Also, we find that some of these forms occur in patches exactly as they grow in nature, and as they would present themselves if they were deposited from water, and not as they would be if they had to pass first through the alimentary canals of mollusca and similar small animals, then through the same organs of fish and birds, in turn, as they would have to do to get into the guano in the manner commonly supposed.

In California we have a deposit of "infusoria," improperly so called, accompanied by bitumen, which bitumen, the gentlemen of the state survey believe, has been derived from those "infusoria," and that contiguous thereto we have guano deposits. Now let us see if we have a similar association of facts anywhere else. At Payta, in Peru, Dr. C. F. Winslow discovered an "infusorial" deposit almost identical in character with the California one. Near by are bitumen springs; and lying off the coast are the guano islands of Lobos, Chincha, Guanape, and others. At Netanai, Japan, we have extensive "infusorial" strata and bitumen; it is not recorded whether guano occurs in that quarter. In the island of Barbadoes we have "infusorial" strata, bitumen, and, near by, the guano islands of the Carribean sea; and, I am informed, guano is abundant on the small islands and rocks nearly throughout the West Indian archipelago. In the island of Trinidad we have "infusorial" strata and bitumen, and, of course, adjacent guano. At all of these localities volcanic action is evident; but we have some localities of guano without "infusorial" strata or bitumen, as yet recorded; while we have the celebrated "infusorial" strata of Virginia, which, by a little stretch of the imagination, may be supposed to be related in some way to the petroleum of West Virginia and Pennsylvania. In Algeria we have "infusorial" strata and bitumen; but I never heard of guano having been found near by. From all of these facts, and others that I have collected of no less importance, derived from chemical and microscopical characters, I have come to the conclusion that guano is not the excreta of birds, deposited upon the islands and main land after their upheaval, but that it is the result of the accumulation of the bodies of animals and plants, for the most part minute, and belonging to the group which Haeckel has included in a new kingdom, separate from the animal as well as the vegetable, under the name of Protista, and subsequently upheaved from the bottom of the ocean. Subsequent chemical changes have transformed it into guano, or, heat and pressure have so acted upon it that the organic matter has been transformed into bitumen, while the mineral constituents are preserved in the beautiful atomies that make up the mass of the extensive "infusorial" strata found in various parts of the world.

The Chincha islands have been visited by a competent geologist, Mr. Kinahan, of Dublin, and he has pointed out that they have been upheaved by volcanic action within a recent period, geologically considered. I have found a remarkable confirmation of my theory in a paper, read before the American Institute, New York, some years since, by Mr. Alanson Nash, detailing the observations of a Mr. F. Nash made during a resi-

dence on the Chincha islands, while engaged in the guano trade, for nearly six months. Therein we find it stated that Mr. Nash was of opinion that guano was formed in the way I have described; that the anchors of vessels in that locality bring up guano from the bottom of the ocean; that "the guano is (much of it) not composed of bird dung, but is composed of the mud of the ocean;" that "the composition taken from the islands, called guano, is stratified, and lies in the same form it did before it was lifted up from the ocean;" that "the bottom of the ocean, on the west coast of Peru, contains vast deposits of guano. An island, during an earthquake, rose up in the bay of Callao, some years since, from the sea, containing guano four feet deep, the formation the same as the Chincha islands." In conclusion, he says, "the day will come when the guano at these islands will be dredged up with boats like mud from our rivers and harbors." And in this expectation I fully coincide with Mr. Nash.

Sea mud has been found to yield an excellent article of fertilizer, and is collected for that purpose at different points along our coast. That from the harbor of Charleston, S. C., yielded to the late Prof. Bailey a rich harvest of diatomaceous forms; and I have examined the same material, as well as that used in Salem, Mass., for the same purpose, and known as "mussel bed," and have found them both to be full of microscopic forms.

Some years since Prof. Gregory described a remarkable deposit of sand from Glenshira, which he considered to be fossil, and called it post-tertiary. It was full of the remains of diatomaceæ, both marine and fresh water, and had been formed evidently by the ingress of the salt water of the bay into a fresh water pond. Occasionally we find the bottom of fresh water marshes upheaved and everted by superincumbent pressure from railroads or other passage ways being built across them. Under these circumstances there are often developed deposits of the remains of diatomaceæ. I have one such specimen from Detroit, Mich. I have also seen two examples of the everting, in this way, of the ancient bed of salt marshes, and in both cases the remains of diatomaceæ are plentiful.

The importance of a knowledge of the diatomaceæ to the geologist has been lost sight of up to the present time; but now that the state of New Hampshire has taken the lead in this matter, it is to be hoped that they will be studied, as they occur in the rocks of other localities.

PART SEVENTH.

Directions for Collecting, Preserving, and Transporting Specimens of Diatomaceæ.

The diatomaceæ constitute a group of organisms of so much interest to the student of natural history, that it is desirable that specimens should be collected in various parts of the world. That such collections may be of value, it is necessary that they should be made in a proper manner; and for the purpose of facilitating the making of such collections these directions have been drawn up. The directions given should be closely followed, as the methods described have been found, after considerable trial, to be those yielding the most satisfactory results. As the fossil deposits containing the remains of diatomaceæ are most readily recognized, gathered, and forwarded, they will be first described.

Fossil Deposits. Included under this head must be considered the enormous sub-plutonic strata found on the Pacific coast of North America, so that the fossil deposits of diatomaceæ may be said to contain both fresh-water and marine species, though never in a mixed state. In some cases the particular species present indicate the character of the piece of water in which the deposit has accumulated, different forms, or groups of forms, appearing in bays, ponds, lakes, marshes, springs, and rivers, and at various points of elevation above the surface of the sea.

The principal fossil deposits of diatomaceæ hitherto discovered contain marine species, and extend over considerable tracts of the earth's surface. The most important stratum of this character is considered to belong to the miocene tertiary, and is found on the Atlantic side of North America, not far from, and, in fact, in some places, reaching down to the coast. It is known to extend from the Patuxent river, in Maryland, as far south as the city of Petersburg, in Virginia. How much beyond these two points it extends has not been ascertained, but is found underlying the cities of Petersburg, Richmond, and Fredericksburg, in Virginia, and at many other points in that state as well as in Maryland. It is desirable to obtain specimens from different points in this bed, as it varies in character, and contained organisms with every few miles of surface, and at different points in its depth.

Strata of this kind vary greatly in appearance, as well as in microscopic character. Therefore the following general directions will suffice to guide collectors in searching for and detecting them.

Gather all earths of light color, varying from a pure white, through different shades of grey, cream, and fawn, to an iron-rust tint. The texture is often friable, and then looks somewhat like clay, especially when it is wet; at other times it is of a hard and stony character, though always more or less porous, and, when soft, of little weight. A moderate magnifying power shows it to be made up of the shells of diatomaceæ. Collect enough to make up three or four pounds' weight, or, say, a block six or eight inches square, and, if possible, from the surface and at various depths, for the reasons already stated. Some of the localities of this material may be mentioned. In Virginia it has been procured in and near Petersburg and Richmond, at Shockhoe hill and Church hill, and at Hollis cliff; and in Maryland, at Lower Marlboro', Nottingham, Piscataway, and Rappahannock cliff.

Besides the above mentioned, an extremely interesting stratum of a similar character, but in general of harder texture, has been found on the Pacific coast of North America, and extending at least from San Francisco to the lower border of California, if not farther, in both directions. This substance makes up the major part of the rocks of the coast range of mountains, and has been named the bituminous shales. It was first detected at Monterey, and is known to microscopists in England as "Monterey stone," but it has since been traced and brought from various points. Santa Cruz, San Pedro, and San Diego have yielded excellent specimens containing many beautiful forms of diatomaceæ. It is usually light fawn-colored, and distinctly stratified. Large fossil shells are found in it; and associated with and in, if not derived from it, is the bitumen of California. At Baldjik, near Varna in Bulgaria, on the Black sea, is a stratum of stony character, having shells and bones dispersed through it. The diatomaceæ found in it are apparently of brackish-water origin, and this is the only stratum of this kind that is known. But very little of this material has found its way into the hands of naturalists. On the island of Jutland, in Denmark, is found a polishing slate which is rich in diatomaceous forms not found anywhere else. This, also, is rare among naturalists, and a good supply of it is very desirable. At Oran in

Algeria, Africa, and at Ægina and Caltanisetta in Greece, are deposits containing the remains of diatomaceæ intermixed with polycystina and foraminifera, and referred to the Cretaceous. In the island of Barbadoes are so-called marls made up of diatomaceæ and polycystina, the latter in great numbers and very beautiful. In the island of Trinidad, at South Naparima, a similar stratum has lately been discovered which "is considered as connected with the new red sandstone; adjoining to which is the sandstone, probably of the same description, in which the Pitch lake is situated." At Moron, in Spain, has been found a similar deposit of marine diatomaceæ; and still another was discovered by Dr. C. F. Winslow at a point about seventy miles south of the town of Payta, in Peru, and about fifteen miles from the Pacific ocean. Here is a plain separated from the sea by a range of hills several hundred feet high. Within the plain is a depression with nearly perpendicular walls two hundred feet high, the bottom of which depression is at about the level of the sea—perhaps a little lower. The surface of the soil thereabouts is covered with salt. For fifteen feet down there is a deposit containing recent shells, the bones of cetacea, and pebbles; then, for one or two feet, is a yellow loam, and, at the bottom, is the stratum, containing the diatomaceæ, which is from two to four feet thick. The amount Dr. Winslow brought away was very small, and this is all that has got into the hands of microscopists. Prof. Pumpelley brought from near Netanai, in Japan, specimens of a like deposit. Very small fragments of the strata from Jutland, Trinidad, Moron, Payta, and Japan have been secured; so it is extremely desirable that those localities should be again visited, the geological relations of the strata ascertained, and a plentiful supply of the material gathered. The sub-plutonic deposits seem to be confined to the Pacific coast of the North American continent, and near by. At Five-mile cañon, near Virginia city, Nevada, is an enormously thick stratum of this character, which is ground and sold considerably under the name of "electro silicon," as a polishing powder. At Klamath lake, on the banks of the Columbia and Pitt rivers, and elsewhere, at many points, these deposits have been found.

The rules already given hold good with regard to gathering specimens of all of these deposits. Everything that can be ascertained with regard to their position and relations should be noted. Also, any fossils con-

tained in them, or in the strata above or below them, should be gathered, and their position noted on the labels accompanying them. All specimens should be kept carefully separate (not even permitting them to come in contact) by wrapping each one in paper, placing within a label having written upon it *in ink* the exact locality, date of collection, and name of collector. It is also desirable that note should be made of the depth from the surface at which the specimen was taken, together with any other information that may be deemed of interest, as supposed extent of stratum, slope-upwards towards north, south, east, or west, and thickness.

Lacustrine Sedimentary Deposits. These were called by me at one time sub-peat deposits, from the fact that all I had seen up to that time had been discovered beneath peat; but as the number of these strata which have come into my hands has increased, I have seen many which do not occur under such circumstances; hence the above name has been applied to them as being more appropriate, and indicating their most common mode of occurrence. In England they are called fossil; but in the true acceptation of that term the forms contained in them are not fossils, but are identical with living species.

They are generally of a pulverulent character, and, when dry, are of little weight, so much so as to attract attention. When free from organic matter, as occasionally occurs, they are quite white, looking almost like powdered starch; but most commonly they are grey, which looks dark while the material is wet, but when dried the color is light. A mass of about six or eight pounds' weight should be secured, and the same precautions as to keeping separate and labelling specimens adhered to, as have been already mentioned. As these beds are seldom of any great extent (they often soon become obliterated or covered up), it will be well to secure a good supply of the material while it is accessible. If any shell, wood, or other organic remains should be found dispersed through the deposit, or overlying or beneath it, they should also be secured, and their position recorded on the label. Likewise, a sample of any superincumbent peat should be kept for future examination. In Sweden and Norway, and in Lapland, these deposits have been used to eke out a scanty supply of flour during bad seasons; but they can hardly be said to be food, for they are not nutritious, but most likely only act by their mass distending the stomach, and thus allaying for a time the pangs of

hunger. They have likewise very frequently been employed, under the name of "tripoli," as a polishing material, and are excellent for that purpose. In some parts of this country they go by the name of "marl," but they are not examples of that substance, which is calcareous, being made up of the remains of the shells of mollusca. Specimens from every locality are desirable.

Muds and Deposits from the bottoms of harbors, bays, lakes, ponds, estuaries, and rivers. As a general thing these are not of very great value to the microscopist for the remains they contain, and it is only desirable to collect them in localities or under circumstances where other gathering cannot be made, or when they are known to contain any organisms of great beauty or rarity. The blacker and softer the mud the better, for, if it contains much sand or gravel, the minute organisms will be present in just so much less proportion. As much as can be conveniently transported, say about a handful, should be collected, and, if possible, not dried, but placed in a bottle and tightly corked; or, it may have a little glycerine added to it, which will prevent its drying,—for it has been found that muds, and especially those from salt-water, when once dried, are only with difficulty broken down again so as to be cleaned. The mud and slime attached to anchors, buoys, and submerged woodwork, together with the scrapings from the bottoms of vessels containing shells, plants, zoöphytes, etc., may be simply dried in the sun, and then have a label attached. The mud from beneath fresh water is of little value, as it rarely contains any organisms of beauty; but the marine forms found in mud are occasionally fine, beautiful, and rare.

Guano. This substance often contains species of diatomaceæ not otherwise obtainable. It is the ammoniacal guanos alone, however, which I have found to yield any great number of diatomaceous forms; but there are certain guanos, of which one known as "Bolivian guano" is an example, partly ammoniacal and partly phosphatic, which contain some forms not otherwise obtainable. Quantities of a pound or two in weight should be secured, and the exact locality of the island or other place from which it was obtained, together with the latitude and longitude, and other information that may be collected and deemed of interest, should be marked *in ink* upon the label.

Shell Cleanings. The sand, mud, algæ, zoöphytes, and similar matters

adherent to marine shells, which are commonly removed by students of conchology, have often been found to yield rich harvests of rare forms of diatomaceæ. Such material can be washed, or, still better, scraped off of the living or dead shells (the dirtier such shells seem the better, of course), placed in paper and plainly labelled with the exact locality, and, if possible, name of the shell and depth of water from which it was taken. Conchologists will do well to save all their shell-cleanings for this purpose.

Marine Invertebrata. Specimens of the entire animal, or the contents of the stomachs of echinoidea (sea urchins) and holothuroidea (sea cucumbers), should be secured, as it has been found that many, if not most of them, are vegetable feeders, and thus take into their stomachs algæ which have diatomaceæ growing upon them. The entire animal should be preserved in spirits (if alcohol is not procurable, brandy or whiskey will answer), but if that be not convenient, they, as well as the contents of the stomachs, may be dried without washing in any way. It has been found that holothurians, when they are immersed in spirit, often turn their stomachs inside out, and thus the contents, which are the part most valuable for the microscopic organisms, will be found at the bottom of the containing vessel. When the whole animal is preserved in spirit, the label may be written in ink on stiff paper or parchment, and, when quite dry, tied to the specimen and immersed with it in the spirit. In this way several specimens can be preserved in the same vessel, and space economized. This method will be found to be the best, as labels pasted or gummed on, or otherwise attached to the vessel, are liable to be obliterated from leakage of the contained fluid, or removed during transportation. The stomachs of mollusca (shell fish) and crustaceans (lobsters, crabs) also occasionally yield specimens of diatomaceæ, and it will be well to secure specimens of those creatures in the manner described. The stomachs of fish occasionally contain diatomaceæ, and may be secured.

Soundings. The material brought up from the ocean bed by the sounding-line, or the larger masses procured by means of the dredge, have been found to yield good returns of microscopic treasures when examined. The calcareous shells of foraminifera, as well as siliceous polycystina and diatomaceæ, are found in them. When kept for this purpose, note should be made of the latitude and longitude, depth of

water, along with the name of the vessel and collector, and the date of collection.

The dust which collects at sea upon the sails or decks of vessels. This kind of material, although not common, has been found to be of interest when examined microscopically. It can generally be scraped up with a piece of paper. When the quantity is so small that it cannot be collected in this way, a piece of damp paper may be laid on it once or twice, in several places, and then folded up before it becomes dry. Latitude and longitude, direction of wind at the time of the falling of the dust, name of vessel, date, and collector's name, should be noted on the label.

Recent gatherings of Diatomaceæ. These are the most valuable, important, and rich of the gatherings containing diatomaceæ on which the student depends for material for investigation, and they are so various in character that it becomes difficult to give general directions that will serve to indicate the modes of procedure to be followed in securing them. To collect diatomaceæ at all thoroughly, a considerable amount of knowledge of their habits is necessary. In general, it may be said that gatherings should be made of marine plants, or algæ as they are called, which grow entirely submerged beneath the water, attached to rocks, piers, iron-, or wood-work. The dirtier such plants appear to the naked eye, the richer will be the harvest of minute organisms secured, as the brown coating, seen upon aquatic plants and similar submerged objects, obscuring them, is but a mass of living diatomaceæ. The larger and coarser algæ,—more especially those having a slimy feel,—do not usually yield many diatomaceæ; but the finer brown, red, or green filamentous kinds are commonly covered with them. Detached fragments thrown up upon the beach ought not to be kept if living ones can be found, for they usually have had the diatoms rubbed off from them, and are, besides, contaminated with sand. The living algæ taken from their attachment should be dried without washing or much compressing, and may then be placed in layers, each specimen being plainly labelled with the exact locality, date of collection, and collector's name. Fragments of algæ, which may break off from cabinet specimens, and would be rejected by students of the algæ, may yet be of value to the diatomist. Some of the finest collections I have ever seen were derived from this source.

When known, the name of the alga should be stated. If possible, it is extremely desirable to secure specimens of diatom-encrusted algæ in spirits. In this way the diatoms will be preserved in almost their natural condition; and those species, which are filamentous or grow in chains, will be available in that condition for study.

Fresh-water plants clouded with diatomaceæ may be collected and preserved in the same manner as marine algæ. As has been remarked, the finer filamentous species of water plants yield the best results; the marine fucoids, as the "bladder wrack," and similar species, secrete a mucus which seems to be repugnant to the growth of most diatoms; yet upon the stalks of Laminaria, and some other large olive-colored algæ, are found the finer red-tinted species, which are themselves beautiful objects of study, and are, in turn, the homes of hosts of minute forms of life. Water plants, marine or fresh-water, should not be cleaned in any way, but merely raised from the water, and, after draining for a short time, be either laid upon a piece of clean paper to dry, or hung up where the air and sun can rapidly evaporate the moisture. Marine plants will usually not dry thoroughly, as the salts present in the water absorb moisture from the air; hence they are liable to mould unless they are packed in paper. The moss-like carpeting seen upon submerged rocks is often made up of beautiful specimens of the filamentous species of diatoms alone, and it will be well to scrape the surface of the stone, and, placing the mass in a bottle, cover it with alcohol, which will become colored from dissolving the coloring matter of the diatoms, and preserve them in the very best manner for future study. Fresh-water forms are very often found hanging in green-colored festoons from the exit pipe of drains, sluices, or fountains, and may be preserved in the same way.

The green, brown, or fawn-colored scum which floats upon the surface of the water of road-side pools, ponds, bogs, marshes, or rivers, consists usually of little else but diatoms, and may be taken up by means of a spoon or bottle, and then preserved in alcohol or dried upon paper. The surface of the sea may be skimmed by means of a net of fine muslin, having an opening left in the bottom, in which a four- or six-ounce wide-mouth phial is tied, and towed at the stern of a vessel. If the sea-water be strained through such a net, either by towing behind a boat or even poured from a pail, the solid matter contained in it will be washed down

and gradually collect in the phial, which can then be removed and tightly corked, and another substituted. Some very beautiful forms have been procured in this way. The stain occasionally seen on the surface of the sea in some latitudes, as well as the minute organisms causing the luminosity of the ocean, yield rich crops of diatoms, and should be secured. Such gatherings may be put up as obtained, or have alcohol added to them for better preservation. The collection of aquatic plants from the mouths of rivers is extremely desirable,—such as have been made in the delta of the Ganges yielding interesting results. The refuse of dredging for shells often yields mud, old shells, or algæ; and collectors will do well to secure such. Experience, however, will teach the best places to look for recent diatoms; but the above general directions will prove of service to those who are new to the pursuit, or who collect for others.

It should always be remembered that a knowledge of the exact locality is of the greatest importance,—so that upon the label should be written *in ink* the locality, date of collection, and name of collector. Other facts deemed of interest may also be added.

PART EIGHTH.

How to Prepare Specimens of Diatomaceæ for Examination and Study by Means of the Microscope.

Having accumulated a number of gatherings of rough material, which, a cursory examination has shown, contain specimens of diatomaceæ, and which, it is judged, it will answer to clean and otherwise arrange and put up, or, as it is technically termed, "mount," for future study, the intending diatomist requires to be informed how he may best set about preparing his specimens in the most advantageous manner. The author of the present sketch has published, in the seventh volume of the *Proceedings of the Boston* (Mass.) *Society of Natural History*, certain directions for collecting, preparing, and mounting diatomaceæ for the microscope; and, as that paper contains a large part of the information he desires to impart at the present time, he will draw upon it pretty freely, supplementing it to such a degree as later investigations warrant, or as may seem desirable.

Although most of the published treatises on the use of the microscope in general profess to give directions for mounting objects in such a

manner as to preserve them for almost any length of time, and at the same time exhibit their characters to the best advantage, and although we have in the English language at least three books treating specially of this subject of the preparation of microscopic objects, yet hardly any one of these volumes gives any concise, practical, and, at the same time, reliable descriptions of the best methods of collecting, preparing, and mounting specimens of diatomaceæ. In books, generally, when the preparation of these organisms is treated of, it is usually the fossil deposits which are considered, and even such directions as relate to these are for the most part meagre and unsatisfactory; and, when the specific and special directions are, as is often the case, copied from one book into the other without having been tested by the copyist, any faults they may have possessed, as originally written, are merely repeated and not eliminated. To prepare and mount specimens of diatomaceæ, for the purpose of sale alone, is one thing, and to prepare and mount them, so as to preserve and exhibit their natural characters and fit them as objects of scientific study, is another and very different thing. The latter can only be attained after considerable practice, and to do it properly a considerable amount of knowledge of their natural history is plainly necessary.

The diatomaceæ should always be prepared and put up for a special purpose,—that of exhibiting characters peculiar to genera and species; and to do this those characters must of course be known. Muds, guanos, dredgings, and gatherings of that description can seldom be used for the purpose of exhibiting such characters, and when they can, in exceptional cases, be so employed, it is when the forms they contain are selected out in the manner to be described hereafter. Gatherings, likewise, which contain many species in a mixed condition, should, as a general thing, be rejected unless there be present something of special importance, such as rare species, or some large and fine or distorted forms of common species. But even in such cases it will be found best not to mount the gatherings as collected, but to select out the forms desired and place them upon slides by themselves, and in such media as will exhibit their peculiarities to the best advantage. Of course it may be desirable to study the geographical distribution of the diatomaceæ; and then mixed gatherings become of value as exhibiting the number of

forms occurring at a particular station. Then, again, the fossil as well as the semi-fossil deposits and guanos may be cleaned and mounted as obtained; but even then it may become desirable, if space can be spared in the cabinet, to have the various species found in each gathering separately mounted, so that they may be at any time studied in comparison with similar forms from other localities.

General directions for collecting diatomaceæ have been already given in Part Seventh; but it will be desirable to again allude to a few points in connection with this portion of our subject. Some years since, an article entitled "Hunting for Diatoms" was published in a London journal called *The Intellectual Observer.* The author's name was not given, but internal evidence would seem to indicate that it was penned by a deceased botanist of note, who was a decided authority on this branch of biology. This paper contains some valuable hints respecting the places in which to look for diatoms, and some of the suggestions contained therein I have ventured to transfer to these pages, as they will be found of value to the intending diatomist. Thus, the exquisite *Arachnoidiscus*, *Triceratium Wilkesii,* and *Aulacodiscus Oregonensis,* may be looked for on logs of wood which have been floating in the sea, and imported from New Zealand, or Vancouver's island. So, on logs from Mexico and Honduras may be found the curious *Terpsinæ musica.* The nets of fishermen, especially from deep water, may yield algæ bearing such forms as *Rhabdoncma arcuatum or Adriatium, Grammatophora serpentina* and *marina,* various *Synedras,* and other fine forms. On oyster shells may be found algæ bearing upon their fronds *Biddulphia regina, Baileyii* or *aurita. Rhizosolenia styliformis* is said to be almost sure to be there likewise. After a ship is unloaded, and as it floats higher in the water, its sides may be searched for treasures of the diatom world, and *Achnanthes longipes* and *brevipes* found, or even *Diatoma hyalinum* and *Hyalosira delicatula.* The sea-grass, or *Zostera marina,* growing along our coast, often bears upon its waving ribbons fine forms of diatoms, and that used for stuffing chairs, and lounges or mattresses, and imported from abroad, will yield foreign species to the collector. There is a plant known in England as "Dutch rushes," which is imported into that country from Holland, and which is used for chair bottoms. These plants grow in the brackish water of the marshes, and hence upon

them are to be found the delicate *Coscinodiscus subtilis*, *Eupodiscus argus*, and *Triceratium favus*. Both of these two last named forms occur commonly on our Atlantic coast, and muds from Charleston, S. C., and Wilmington, Ga., have provided me with them in plenty. Cargoes of bones, which present green incrustations from having lain in the water for some time, are said to yield diatoms, some of which may be rare, as coming from foreign ports. The state of New Hampshire has not yet been sufficiently gone over for it to be said what the characteristic forms of diatomaceæ growing within its boundaries are, but yet we may safely predict that the lakes, ponds, streams, and sea-coast of that state will yield to the searcher ample material of beautiful forms.

If the microscopist wishes to mount a few slides of recent diatoms just to show what diatoms are, nothing is easier. It is only necessary to boil a small mass of them in strong nitric acid in a test tube over a spirit lamp, and, when the acid has ceased to emit red or yellowish fumes, wash them thoroughly with clean water, allowing them to settle completely. Then a little of the clean sediment, consisting almost entirely of the shells of the diatoms, is taken up by means of a "dip-tube," and placed upon the central portion of a glass slide. Here it is dried, and the slide warmed over a lamp; then a drop of Canada balsam is permitted to fall upon the diatoms. As soon as all bubbles have cleared off from the balsam, a warm cover of thin glass is carefully laid upon it and permitted to settle into place. When cool, it is ready for examination by means of the microscope, any balsam which has exuded around the cover being washed off with alcohol. In this way rough and tolerably clean specimens may be obtained; but such would not, or, at all events, should not, satisfy the student of the diatomaceæ. For him more elaborate methods are necessary, and these we will now proceed to consider.

Apparatus and chemicals necessary. A chemist's retort-stand, which is a heavy iron plate with an upright rod projecting from one side of it. Running on this rod, and so arranged that they may be fixed by set-screws at any height, are a series of rings of various diameters, which are to be used to hold the vessels in which the specimens are to be manipulated over the source of heat used. Mr. C. G. Bush, late of Boston, Mass., who has had considerable experience in cleaning diatomaceæ, tells me that he uses a lamp burning petroleum oil, as cheaper than a

spirit-lamp, and, to support the vessels he employs, has a little metal arrangement on the top of the chimney, such as is supplied for the purpose of holding a small tea-kettle and the like. The only objection to the oil-lamp is, that, unless the wick be well turned down, we are liable to have our vessels blackened. However, the heat given off by burning petroleum is very great, and I have often used such a lamp with advantage. If desired, of course, the source of heat used may be gas, burned in a Bunsen's burner, or a spirit-lamp; and this last, especially if it be supplied with a metal chimney to cut off draughts, is, all things considered, the best, as it is very cleanly, not being liable to smoke the bottom of the glass or porcelain vessels used. If we are going to work with large quantities of material, we shall require a small sand-bath to heat the glass vessels upon. In small quantities, the diatoms may be boiled in test-tubes, when some sort of holder will be required. The metal ones, sold by dealers in chemists' apparatus, are extremely handy; but I have found that we can make very good ones out of old paper collars. One of the kind called "cloth-lined" may be cut into strips about three quarters of an inch wide and three inches long. Such a strip is folded around the test tube, near the top, and the ends, brought together, are held between the fore-finger and thumb. In this way the tube is firmly grasped, and can be held over the lamp without much danger of burning the hand, as the paper collar strip is a bad conductor of heat; or, the paper strip may be grasped in an "American clothes-peg," which has a spring to force its parts together. Large quantities of diatoms are best boiled in porcelain evaporating-dishes, glass flasks, or beaker-glasses. The last mentioned vessels are also by far the best things for washing them in. A few, say three or four, glass stirring-rods will be found useful; and one or two American clothes-pegs to take hold of hot evaporating-dishes with. Then there will be required a few dip-tubes, made of small glass tube, drawn out over a flame, so that the opening is considerably diminished. The mode of making these cannot be given here, but will be found in books on chemical manipulation; and it will be well for the student to learn to make his own dip-tubes, as a number will be required first and last, and they are easily broken. Of course there will be required a number of glass slides, of the usual dimensions of three inches by one. These should be of as white glass as possible, and it will

be found best to procure those with ground edges, as they are the neatest in appearance. Only such as are free from scratches or other blemishes in the central square inch should be used; and, although even such as have bubbles or scratches near the ends only will not look ornamental in a cabinet, we should remember that microscopic objects are not generally mounted to look well in a cabinet, but to be useful out of it; so that if the central and useful portion of the slide be perfect it need not be rejected. Some persons make their own glass slides, but I have never found it answer to do so, as it is difficult to get the right kind of glass, not at all easy to cut it or grind the edges, and it is liable to be scratched while cutting or grinding. Thin glass, such as is made on purpose for microscopic use, will be required; and this, also, it will be found best to buy ready cut rather than attempt to cut it for one's self. The thin glass used for covers may be of different thicknesses, but the thickest made will not do for diatoms, and a certain amount of the very thinnest will be required for small and delicately marked forms, on which very high power objectives will have to be used. The covers must be perfectly clean, which may be insured by soaking in caustic potassa solution, and then washing thoroughly in clean water. The thinner kinds of glass are rather difficult to clean; but with a little extra caution it may be accomplished, the last polish being given to it by a piece of an old and well-worn cambric handkerchief. The covers, always round, should be separated into sizes and thicknesses, so that the exact kind of cover required can be found without having to search for it by turning over a number, scratching or breaking them, and losing much valuable time. We shall also require a pair of forceps for holding the slides over the lamp; and such as are sold at house-furnishing stores and by grocers, under the name of American clothes-pegs, and which have been already mentioned, are by far the best I have ever seen or heard of. A small pair of brass forceps which close with a spring will be needed, and they are best set in a wooden handle so as to protect the fingers from the heat; and another pair, which spring open and may be closed by means of the finger and thumb, will be wanted for taking hold of and adjusting the thin covers. I do not advocate the use of paper covers for slides, but labels of some kind will, of course, be required, and I have found the plain circular white ones to look the best. There are very pretty square labels sold by dealers

in these things that I have used and liked. For making cells to hold specimens put up in fluid, a turn-table and brushes and some cement will be necessary. The cement I use and prefer above all others is good old gold size, used warm.

The chemicals required are nitric acid, sulphuric acid, hydrochloric acid, bichromate of potash, caustic potash, alcohol, and, above all, a plentiful supply of clean, *filtered* water. The water should be such as leaves hardly any residuum when a quart of it is evaporated to dryness; and it must be filtered just before use, to remove any minute organisms, diatoms especially, which it may contain. A certain amount of washing soda will be wanted, if guanos are to be cleaned.

We will now proceed to consider the manipulations necessary to prepare the various kinds of gatherings, always remembering that these methods will have to be modified to a certain extent for each specimen.

Recent Gatherings. If there be sand in the gathering, it will be well to remove it before using acid by shaking it in clean water and pouring off before the diatoms, which are lighter than the sand, settle. The water holding the diatoms in suspension may be poured into a test-tube or beaker, the diatoms allowed to settle, and as much of the water poured off as possible. The diatoms are now covered with nitric acid to about the height of half an inch, and allowed to stand for a few minutes. Usually, some chemical action takes place, and it will be well to wait until it subsides. The test-tube or beaker is then held over the lamp and carefully heated until the reaction of the acid upon the organic matter of the diatoms ceases. Thereafter, and while the liquid is still hot, I have found it often advantageous to drop in one or two fragments of bichromate of potash. The organic matter is more thoroughly destroyed in this way than when the acid is used alone. Thereafter it is well to pour the acid and diatoms into a capacious beaker of clean water, washing the tube or smaller beaker out with a little water, and adding this to the other. After the diatoms have all settled, which will often require hours, the supernatant fluid is carefully poured off, and a fresh supply added; and this must be repeated several times until all of the acid and colored chromium compound has been removed. When this point is arrived at can only be ascertained from experience. In this way the valves and connecting membranes of the diatoms are usually separated

and cleaned ready for mounting, which process will be described hereafter.

Muds will have to be treated in a somewhat different manner from recent gatherings. If the mud is dry, it will have to be broken down by boiling for a few minutes in a solution of caustic potassa, the strength of which must be apportioned to the particular specimen under treatment. After it has been broken down into a soft mud, all of the potash is thoroughly washed off by means of clean water, and replaced by nitric acid, as in the case of recent gatherings. This is boiled, and a little bichromate of potash added as before, and the whole washed. It very seldom happens that the diatoms occurring in mud will be sufficiently cleaned by this process, so that it has to be supplemented by another. The sediment is therefore washed into one of the evaporating-dishes and allowed to settle, and as much of the water poured off as possible. Then sulphuric acid, in quantity to a little more than cover them, is poured in, and the vessel gradually and carefully heated. As soon as the liquid shows signs of boiling, bichromate of potash is added, a very little at a time, until the green color first formed by its reaction upon the organic matter begins to assume a yellowish tint, when no more is dropped in; but a few drops of hydrochloric acid are permitted to fall in, and the liquid is allowed to cool. Of course it will be best if the person undertaking to clean diatoms is somewhat versed in the use of chemicals; but at any rate care must be taken not to drop any of the acids upon the clothes or skin, and great caution must be exercised in not inhaling any of the vapors given off. Those evolved after the addition of the hydrochloric acid are especially irritating and dangerous, and must be avoided. As soon as the liquid has cooled a little, water should be added cautiously, as great heat will be generated thereby, and there will be danger of its boiling over. Thereafter it may be poured into a large beaker-glass of water and thoroughly washed, as in the former case. If it be found that the precipitate is not quite white, it will be necessary to boil it again in sulphuric acid, with bichromate of potash and hydrochloric acid, until it is quite clean. If, on examination by means of the microscope, it is found that there is much flocculent matter present besides the diatoms and sand, this can be removed by boiling for a few seconds in a weak solution of caustic potash, and washing quickly and thoroughly

with plenty of clean water. When we have recent gatherings of filamentous or stipitate forms of diatomaceæ, which we desire to preserve in the natural condition, they should be immersed for about twenty-four hours in alcohol to dissolve out the endochrome. If this does not answer, it will be well to soak the mass of diatoms or plants upon which they are adherent in a solution of hypochlorite of soda, an impure variety of which is sold in the shops under the name of Labarraque's disinfectant, for about the same length of time. This will generally destroy all color, and leave the specimens transparent. It is best, however, in many cases not to remove the endochrome, but leave it, and mount the specimens in such a way as to show them in as natural a condition as possible. How this may be done will be described hereafter.

Guanos. The preparation of these substances so as to obtain the microscopic organisms they may contain is rather difficult, tedious, and dirty, and should only be undertaken by a person somewhat versed in chemical manipulations, and in a proper room as a laboratory, where there is no danger of harm resulting from the fumes evolved. As the ammoniacal guanos are those which contain the most diatoms, and consequently which answer best to clean, we will begin with them, and take as a type that which comes from the islands on the coast of Peru. As it comes into commerce this guano is a moist powder of a light iron-rust color, smelling strongly of ammonia, and having scattered throughout its mass lumps of ammoniacal salts of a more or less solid consistency. The guano should be thinly spread out upon a stiff piece of paper and exposed to the air, and, preferably, to a moderate heat for several days or even weeks. In this way most of the moisture and much of the ammonia will evaporate, and less acid will be required to clean the guano. It will now have become much lighter in color, and crumble to a dry powder. A tin pan is now about half filled with a solution of common washing soda in clean filtered water, and placed over some source of heat, as on a stove. The strength of this solution is not a matter of any great moment, and must vary with the guano manipulated. As soon as it begins to boil, the guano is dropped gradually in, a little at a time, while the liquid is stirred with a glass rod or stick of wood. Considerable effervescence takes place, ammonia being given off, and therefore it must be kept continually stirred, and care exercised to prevent its boiling over.

After a while it is poured into a plentiful supply of clean water and washed therewith several times, care being taken to permit all of the diatoms to settle. As soon as the wash-water is only slightly colored, the guano is transferred to a good sized evaporating-dish, and covered with nitric acid, and boiled. While it is boiling, a few crystals of bichromate of potash are dropped in, and the material washed as in the case of muds. Thereafter the diatoms are boiled in sulphuric acid with bichromate of potash and hydrochloric acid, as before described.

Phosphatic guanos, as that from Brazil, are somewhat more difficult to treat. They are generally drier than the ammoniacal kind, and must be boiled in a large quantity of hydrochloric acid as many as three times, and the acid must be poured off while still hot. Thereafter nitric acid and sulphuric acid and bichromate of potash must be employed, as in the other case.

Lacustrine Sedimentary Deposits. For the most part these are pulverulent, and easy to clean. Some, as found in nature, are so pure that they require no cleaning except washing in clean water. Burning on a plate of platinum or mica will often serve to clean some specimens, but it will, in general, be found best to boil in nitric acid with a little bichromate of potash, and subsequently in sulphuric acid and bichromate of potash, with the after addition of hydrochloric acid. Occasionally a certain amount of flocculent matter will be left, which it will be necessary to remove with very careful heating, not boiling, in a weak solution of caustic potash, and immediately pouring into a large quantity of clean water and thoroughly washing.

Marine Fossil and Sub-Plutonic Deposits, being stony and possessed of very much the same physical characters, are manipulated in the same manner. A small lump of the deposit is placed in a test-tube, and covered with a strong solution of caustic potash. It is then boiled for a few minutes, and usually it immediately begins to break up and fall down in the shape of a soft mud-like material. At once the liquid, with the suspended fine powder, is poured off into a large quantity of clean hot water, and if the whole of the lump has not broken down into a powder, what remains has a little water poured over it in the test-tube, and it is again boiled. It will be found that a little more will now crumble off. This is added to the rest in the large vessel, and if the lump has not now broken

down, it is again boiled in the alkaline solution and in water alternately, until it has all been disintegrated. It is then all permitted to settle for at least three hours, when it is thoroughly washed and boiled in hydrochloric acid for about half an hour. There is then added an equal amount of nitric acid, and the boiling continued for a short time. It is then washed and heated in sulphuric acid, with the addition of bichromate of potash and hydrochloric acid.

All mixed gatherings of diatomaceæ, and particularly all muds and deposits, should be separated into densities, so that for the most part the larger forms are collected together, free from sand, and separate from the smaller species and broken specimens. This is done by using a number of beaker glasses, of various sizes, in the following manner: Into a one-ounce beaker the cleaned diatoms are placed, and the vessel filled with water. It is then well stirred up by means of a glass rod, and, after resting about five seconds, poured off carefully into a six-ounce vessel so as not to disturb the sand which has settled. Again the vessel is filled up with water, stirred, allowed to settle for the same length of time, and poured into the same vessel. This is repeated until it has been done at least six times, when we shall find all of the sand, free from diatoms, in the small beaker. This can be thrown away, and as soon as the material in the large beaker has settled it is returned to the small one, and the same process gone through with, only extending the time of settling now to about ten seconds. The next density is that which settles in twenty seconds; and so on, five or six densities may be obtained, and if carefully prepared they will be found to contain forms varying very much one from the other. The large species of *Triceratium*, *Aulacodiscus*, and the like, will be found in the coarsest density, and the broken diatoms in the lightest.

Preserving and mounting specimens so as to have them in a condition for study at any future time. Of course, when possible, diatomaceæ should be studied in the living condition. But there are many forms which have not been as yet found living, and these can only be studied as dead skeletons; and, in fact, it is in the dead skeletons of the diatomaceæ that many of the most marked characteristics are to be found; and on such characteristics species have been founded. Besides, the most beautiful sculpturing of the valves is only to be seen after every-

thing has been removed but the siliceous cell-wall I have termed the skeleton. Therefore I advocate the cleaning of a portion at least of every gathering in the manner described, so that nothing will be left but the clean siliceous cell-wall.

If we desire to keep specimens in a state as near that they present when living as possible, we have to put them up in some preservative fluid in which they will not decay, and in which the softer parts will be preserved. Unfortunately these soft parts do not keep well; but the fluid which I have found to be the best for the purpose is distilled water, which has to every fluid ounce two or three drops of wood creosote added, and thereafter a sufficient number of drops of alcohol, which will be about double the number of the drops of creosote, to make the creosote soluble in the water, which it is only to a very slight degree under ordinary conditions. I do not advocate any fluid containing glycerine, or, in fact, any of the preservative fluids described in the books treating of the preparation of microscopic objects. The vessel in which the fresh specimens of diatomaceæ are put up are what are known to microscopists as "cells," but how these are made cannot be gone into here, as the description would occupy too much space and time. Suffice it to say that I prefer cells made of old japan gold-size, which can be procured of dealers in microscopic materials. Within such a cell, of sufficient depth and immersed in the preservative fluid, a few of the diatoms, or a scrap of the plant upon which they are growing, is placed, and the glass cover fixed over it in the manner described in the books upon manipulation. The filamentous forms are thus preserved almost in their natural condition; but, on account of the presence of the endochrome, the sculpturing of the siliceous cell-wall is almost invisible. To show this character, while the filamentous form is preserved, another method of mounting is employed. A thin, clean covering glass is selected, and laid upon a clean piece of paper. A large drop of distilled water is then allowed to fall upon it, and in this drop the filamentous diatom is thinly spread out. Then the cover is taken up by means of a pair of forceps and held over the flame of a spirit-lamp, which has been turned down so as to be quite small and steady. The cover is held some distance above the flame, and judiciously manipulated, so that the heat is evenly distributed over it, and it does not crack. As soon as all

the water has been driven off without the formation of bubbles, the glass is brought gradually down almost in contact with the flame, and held at that point for a few minutes. Then the diatoms will be seen to turn black, on account of the charring of the organic matter contained in them. After a while this black carbonaceous matter will burn off, and they will become quite white. If, however, there seems to be any difficulty in burning off the last portions of carbon, the cover is lowered once or twice to come in contact with the top of the flame, and then raised again. In this way it will become red hot for a moment; and everything will be burned off except the siliceous portions of the diatoms. Now the cover is removed slowly from over the flame, and held in the forceps until it is cold, but by no means laid down upon any surface until it is quite cold,—otherwise it will fly into pieces. Then it can be laid upon an ordinary glass slide, and examined to see if it is worth preserving, which may be done in one or two ways: first, the glass cover is warmed, and a drop of good spirits of turpentine let fall upon it, covering the diatoms. Just before the spirits evaporate, a small drop of thin Canada balsam is added, and a slide taken, warmed, and a drop of balsam placed upon the centre part of it. Then the cover is brought down upon the slide, the two balsam-covered sides together, in such a way, by tilting the cover slightly, that no air is allowed to come between them, and the cover permitted to fall gradually into place, driving a wave of balsam before it. In this way we have the filamentous diatoms arranged as they grow, but with endochrome removed which would obscure the markings, and in balsam, which renders them transparent. Some forms, as some of the *Fragillariæ*, become too transparent if put up in this way, and therefore another method of mounting must be adopted with them. They are burned upon the cover, as just described, but mounted dry in air; that is to say, a cell of gold-size is made, the glass cover slightly warmed, and then placed upon the cell, with the side upon which the diatoms are fixed, downwards. The warmth slightly softens the gold-size, and the cover becomes fixed.

Other forms besides the filamentous species may be mounted in fluid, or burned upon the cover and subsequently put up in balsam, or dry. But the commonest way of treating such forms is to clean them by means of chemicals, as already described, and then previous to mounting them

divide the clean gathering, consisting of a white sediment of large and small diatoms along with fine sand, all mixed up together into densities. Of course, if some of this sediment were to be mounted in this condition, extremely unsightly slides would be procured; so it is best to separate the finer from the coarser diatoms, and these in turn from the sand. This is accomplished by what is known as elutriation, or, separating into densities after the manner already described. Then slides may be mounted from each of the densities in the following manner. A slide is thoroughly cleaned, and a good sized drop of water placed upon the centre portion. A little of the diatom sediment is then taken up in a dip-tube, and the point of the tube brought just into contact with the drop. As soon as a few diatoms have run out of the dip-tube, it is removed. Then a small splinter of wood or stiff bristle is used to disseminate the diatoms through the drop of water in such a way that they will be pretty evenly distributed and not overlie each other. The water is then driven off by heat, a drop of thin Canada balsam placed upon the dry diatoms, and a cover placed on them in the usual manner. In many cases, especially when dealing with the smaller forms, it will be found desirable to mount them upon the cover in this same way, instead of upon the slide, as they will then be brought as near as possible to the objective of the microscope. Single or remarkable specimens of diatoms may be picked out and mounted by themselves; but the manner of accomplishing this would occupy more space than it has been thought desirable to devote to this portion of our subject, and the reader is referred to the books on mounting microscopic objects for the particulars of the process.

The main principles of preparing and mounting diatomaceæ for preservation and study have been given, and the intending student will be able to devise modifications and improvements for himself, so that he will be able to put up specimens in as finished a manner as any to be procured from the dealers.

Description of Plates.

All of the figures, with the exception of 23 and 24, are magnified five hundred diameters, or two hundred and fifty thousand times superficial. Fig. 23 is magnified about three hundred diameters, and Fig. 24 one hundred diameters. All of the figures, with the exception of the two mentioned, are exact portraits of specimens in the collection of the author, and are intended to be as perfect delineations of the diatoms represented as could be obtained, as the drawings have been made with special care to that end. This fact is mentioned, as most of the plates of diatoms published do not give correct ideas of these organisms, and are usually drawn or engraved by persons not possessed of an intimate acquaintance with the objects intended to be represented. The plates have been obtained by photography direct from the author's drawings, without the intervention of any engraver, and are, therefore, truthful reproductions of them.

Plate I.

Fig. 1. Front view of *Triceratium Montereyii.* From the marine fossil "infusorial stratum," of Monterey, Cal. This figure shows the connecting membrane, which is differently sculptured from the valves.

Fig. 2. Front view of *Triceratium punctatum.* In this specimen no connecting membrane has been developed. From the harbor of Charleston, S. C.

Fig. 3. Side view showing the valve of *Pinnularia nobilis.* From Germany.

Fig. 4. Front view of *Rhabdonema arcuatum.* From the harbor of Salem, Mass.

Fig. 5. Side view of *Pleurosigma angulata.* From the coast of France.

Fig. 6. Side view of *Pleurosigma fasciola.* From the harbor of New Haven, Conn.

Fig. 7. Side view of *Triceratium punctatum.* From Charleston, S. C.

Fig. 8. Side view of *Pleurosigma Balticum.* From the coast of England.

Fig. 9. Side view of *Pleurosigma quadratum.* From the coast of England.

Fig. 10. Side view of *Coscinodiscus radiatus.* From the marine fossil stratum of Oran, Algiers. In this specimen, as is very commonly the case, the radiant arrangement of the markings is obscure.

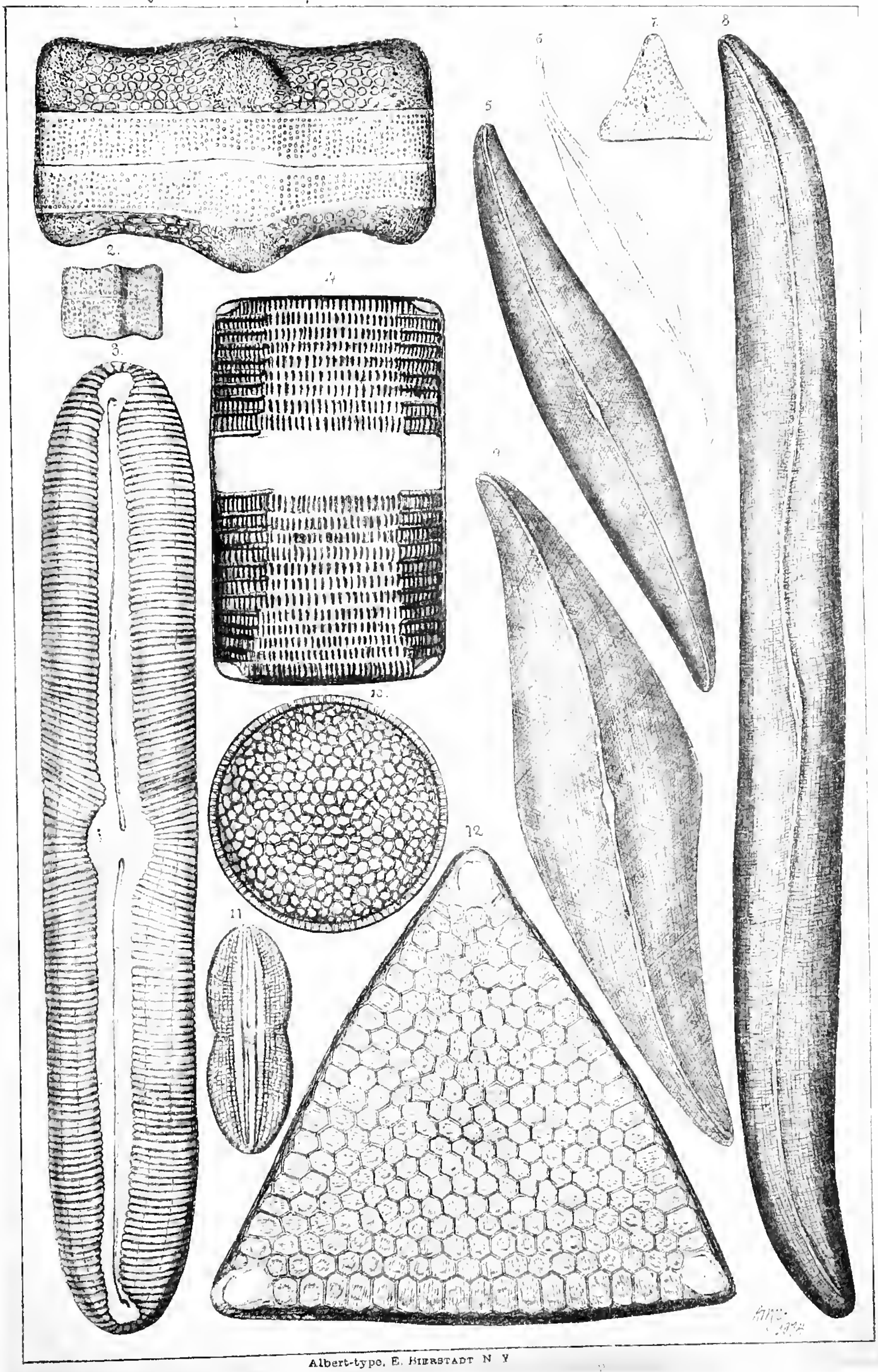
Fig. 11. Side view of *Navicula didyma.* From the coast of France.

Fig. 12. Side view of *Triceratium favus.* From the harbor of Charleston, S. C.

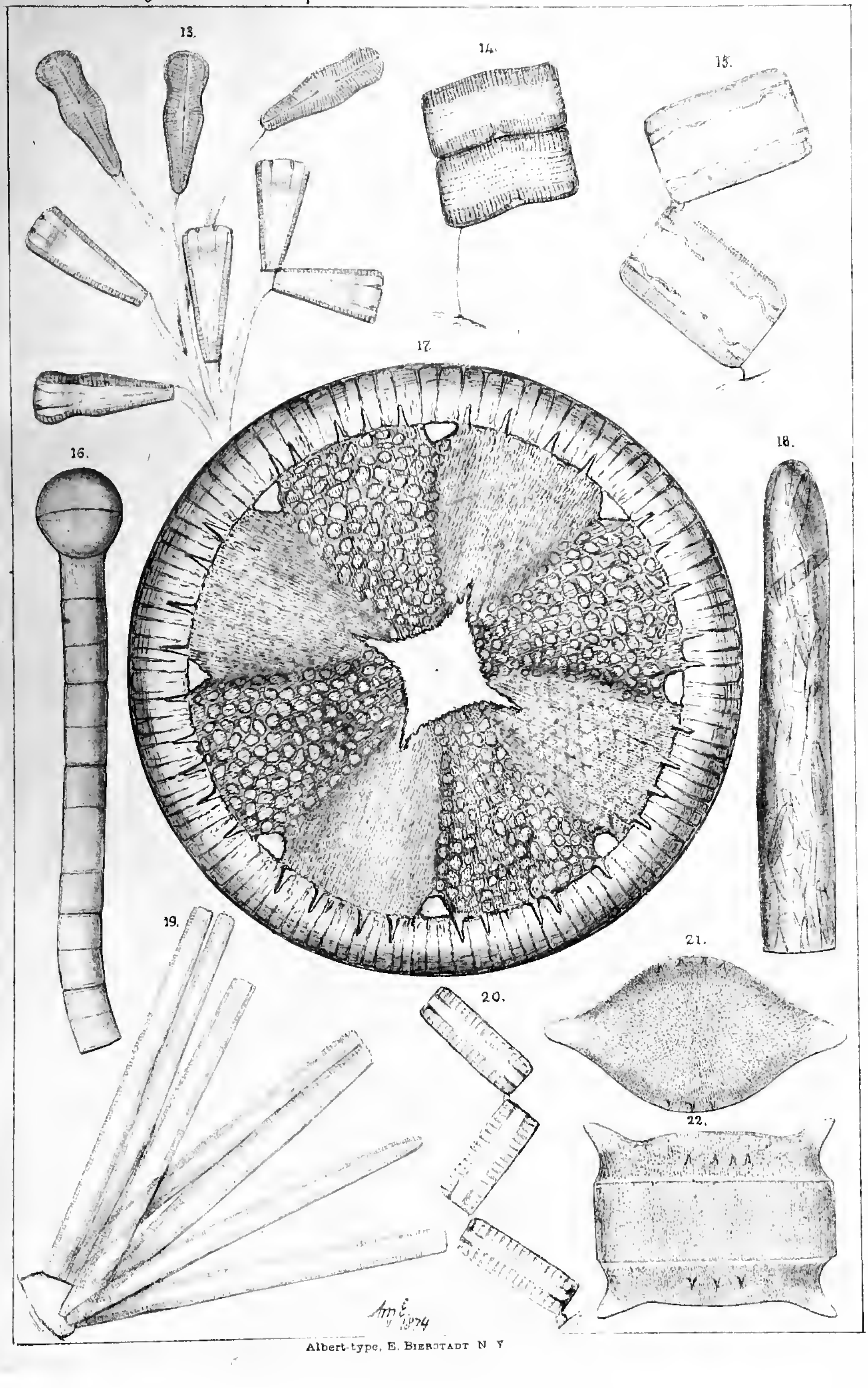
Plate II.

Fig. 13. A specimen showing both front and side views of *Gomphonema constrictum,* as well as the arrangement of the stipes or stalk. From Marion, N. J.

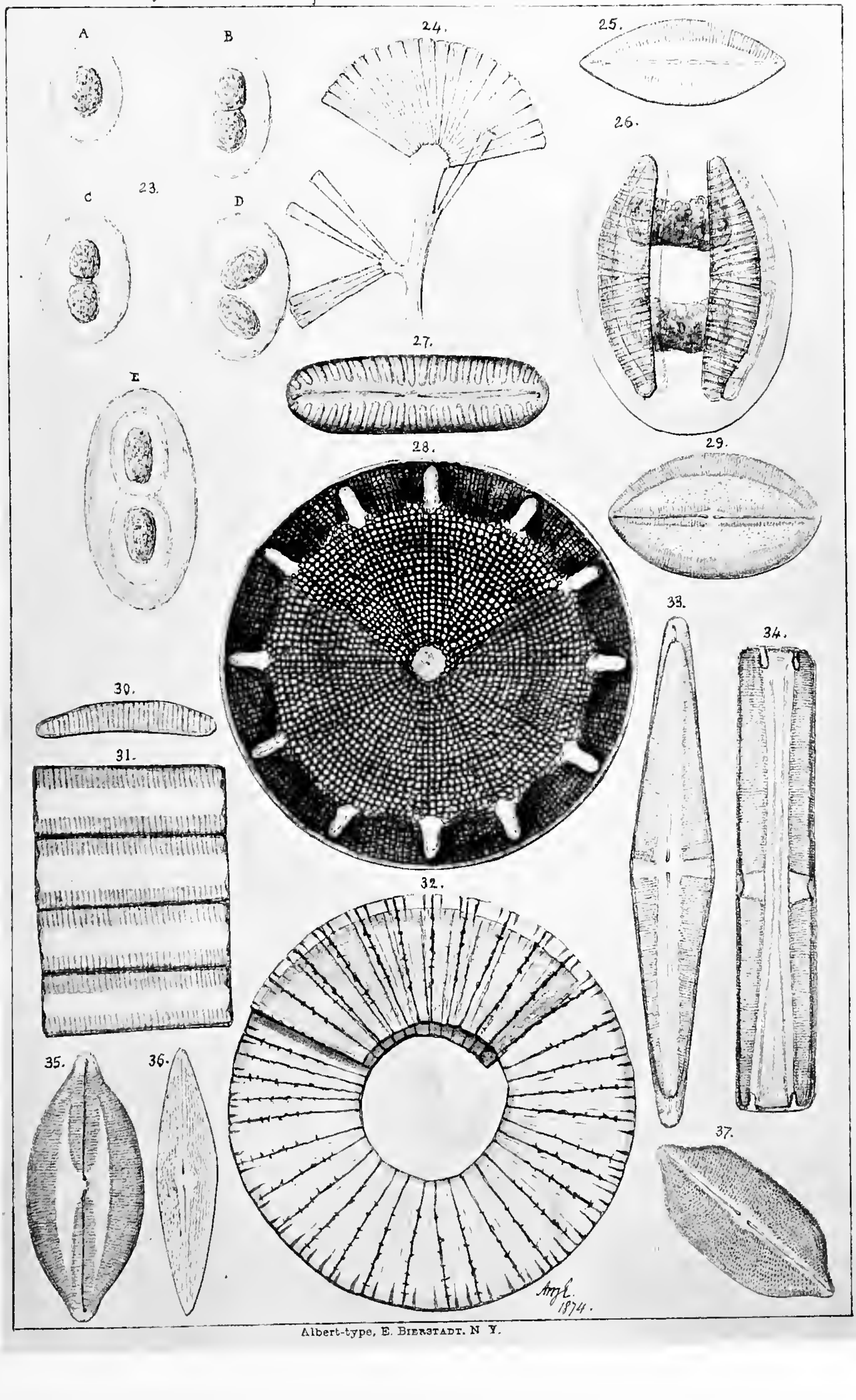
Fig. 14. Front view of *Achnanthes brevipes,* showing the flag-like appearance of the perfect individual when attached to some submerged substance by means of its stipes. From the coast of England.



Albert-type, E. Bierstadt N Y



Albert-type, E. Bierstadt N. Y.



Albert-type, E. Bierstadt. N. Y.

Fig. 15. Front view of a chain of two frustules of *Grammatophora marina*, from the harbor of Salem, Mass.

Fig. 16. Front view of a filament of *Melosira varians*, terminated by a sporangium or seed vessel. From Englewood, N. J.

Fig. 17. Side view of *Heliopelta Metii*, from the marine fossil stratum of Nottingham, Md. The species has been lately removed from the genus *Heliopelta* and placed in *Actinoptychus*, and can therefore be considered as a representative of that genus. It is one of the most beautiful of the diatoms, and has never as yet been seen except in the fossil condition, and at the locality named.

Fig. 18. End and portion of a tube of *Schizonema obtusum*, from the harbor of New York. The little navicula-like frustules of the *Schizonema* are seen within the tube.

Fig. 19. A group showing both front and side view of *Synedra tabulata*, from the harbor of New York, showing the manner in which the frustules are attached to submerged objects by means of a cushion or short stipes.

Fig. 20. A chain of *Diatoma vulgare*, from England, showing the front view only.

Fig. 21. Side view of *Biddulphia rhombus*. From the harbor of Charleston, S. C.

Fig. 22. Front view of *Biddulphia rhombus*, showing both valves and connecting membrane. From the harbor of Charleston, S. C.

Plate III.

Fig. 23. A, B, C, D, and E, different stages of growth of *Palmoglœa*.

Fig. 24. *Lichmophora flabellata* on its stipes or stalk. From the coast of England.

Fig. 25. Side view of *Navicula Barklayana*. From the coast of England.

Fig. 26. *Epithemia turgida*, conjugating or reproducing. From England.

Fig. 27. Side view of *Pinnularia lata*. From New Hampshire.

Fig. 28. Side view of *Aulacodiscus Oregonensis*. From the Sandwich islands.

Fig. 29. Side view of a *Navicula prœtexta*. From the Gulf of Mexico.

Fig. 30. Side view of *Himantidium pectinale*.

Fig. 31. Front view of a filament of *Himantidium pectinale*, from a spring near New York.

Fig. 32. Side view of *Meridion circulare*, showing the wedge-shaped frustules united together so as to form a spiral. From West Point, N. Y.

Fig. 33. Side view of *Stauroneis acuta*.

Fig. 34. Front view of *Stauroneis acuta*. From England. In these two figures the septum, which projects like a shelf into the cavity of the frustule at the ends, can be seen.

Fig. 35. Side view of *Navicula lyra*. From Germany.

Fig. 36. Side view of *Navicula serians*. From New Hampshire.

Fig. 37. Side view of *Navicula quadrata*. From Germany.

APPENDIX.

NEWARK, N. J., September 1, 1874.

Prof. C. H. HITCHCOCK, State Geologist:

Dear Sir—As you request, I send what information I can at the present time concerning the specimens of diatomaceæ which I have received from you or others, or collected myself in the state of New Hampshire. The specimens have been of two characters. For the most part they have consisted of lacustrine sedimentary deposits, and these have been collected by yourself, or the other gentlemen connected or not connected with the survey. A few recent gatherings have likewise been sent to me by you, or procured by myself and a friend, in and around Hanover and elsewhere. The lacustrine sedimentary deposits are thirteen in number, and are from the following localities: Bemis lake, Carroll county; Bowkerville, Fitzwilliam; Stamp Act island, near Wolfeborough; Littleton; Laconia; Bristol; Chalk pond, Newbury; Epsom; Pike's pond, Stark; Bow; Cold pond, 2000 feet above the sea, one eighth mile from Crawford house; Umbagog lake, Coös county; Concord. Besides these, I have received prepared slides from Manchester and from Durham.

As it may be of interest to those who study the diatomaceæ to know, I will state when and how these deposits came into my hands.

Bemis Lake. The first specimen of this deposit was sent to me by Mr. Charles Stodder, of Boston, Mass., in 1859. I examined it and published a list of the species I found in it at that time in the *Proceedings of the Boston Society of Natural History,* May 2, 1860. This list is as follows:

Cocconema parvum.

Cyclotella Kützingiana.

Cymbella cuspidata.

Eunotia serra.

Gomphonema acuminatum.

Himantidium gracile.

Navicula affinis; Navicula cuspidata; Navicula firma; Navicula interrupta; Navicula rhyncocephala; Navicula serians.

Nitzschia ——— ———?

Pinnularia major; Pinnularia stauroneiformis; Pinnularia tabellaria; Pinnularia viridis.

Stauroneis phœnicenteron.

Surirella biseriata; Surirella linearis.

Tabellaria fenestrata; Tabellaria flocculosa.

I have again and more carefully examined this deposit, and find that I have to make some corrections in the above list, as well as add to it; but, as my investigation has not been completed, I shall not at the present time make these corrections and addi-

tions. Besides the specimen sent me by Mr. Stodder, I received further supplies from Mr. R. C. Greenleaf, of Boston, in 1866, and from the discoverer and owner of the deposit, Dr. S. A. Bemis, in 1865 and 1870.

Bowkerville. The first specimens of this deposit which I received were from yourself, in May, 1871. In the following July I visited the locality with you, and made further collections.

Stamp Act Island. This deposit I received from you in September, 1871.

Littleton. The first samples of this deposit were procured from the Bailey collection in the possession of the Boston Society of Natural History, and were sent me by Mr. Charles Stodder. Subsequently specimens were sent to the survey by Mr. B. W. Kilburn, and were transmitted by you to me.

Laconia. The first specimens of this I received from Mr. R. C. Greenleaf, in November, 1865. In May, 1867, he sent me a further supply, and told me that it occurred on a farm belonging to Col. Crockett.

Bristol. This was sent to me by Mr. C. Stodder, June, 1862, who said that he had received it from a Mr. Webster.

Chalk Pond, Newbury. A very small sample of this deposit was sent to me by you, October, 1871; and in June, 1874, you sent me a further supply.

Epsom. This I procured from the collection of the Essex Institute, Salem, Mass., in December, 1864.

Pike's Pond. This was discovered, I understand, by Mr. J. H. Huntington, of the survey, and was given me by you, June, 1871.

Bow. This I also procured from the collection of the Essex Institute, and it was labelled as having been presented by Dr. Prescott.

Cold Pond, near Crawford House. A very small sample of this was sent me by you, July, 1872.

Concord. This I procured from the Bailey collection in Boston.

Umbagog Lake. This you sent me in July, 1870.

The slides labelled *Manchester, N. H.*, and *Durham, N. H.*, I received from Mr. E. Samuels, of Boston, Mass.

The recent gatherings of diatomaceæ which I have from New Hampshire, are as follows:

No. 1. Brook emptying into Shaker pond, Enfield.
No. 2. "Muck hole," Hanover.
No. 3. On mosses from Shaker pond, Enfield.
No. 4. Mink brook, Hanover.
No. 5. Trout pond on farm of J. E. Lawrence, Bowkerville.
No. 6. Lake of the Clouds, on Mt. Washington.
No. 7. Haystack lake.
No. 8. Large pond, Bowkerville.
Nos. 9, 10, 11. Hanover.

All of these, with the exception of Nos. 6 and 7, are my collections. Nos. 6 and 7 you sent me.

Besides these gatherings, I have received fresh-water diatomaceæ from the following localities in New Hampshire, through the kindness of Mr. R. C. Greenleaf, of Boston, Mass.:

Lake Mouran, on Cannon mountain, 1865.

Saco river, 1865.

Echo lake, 1865.

Profile lake, 1865.

Spring near Tip-top house, Mt. Washington, 1865.

Small pond near Crawford's, 1865.

Spring near Lake Mouran, 1865.

Pond on Mt. Lafayette (Lake Greenleaf).

Snow arch, Tuckerman's ravine.

Androscoggin river, Gorham.

Gibbs falls, Crawford.

Brook in Bethlehem.

In June, 1862, Mr. Charles Stodder sent me a specimen of a lacustrine sedimentary deposit, labelled "New Hampshire: locality and history entirely unknown; sent by some one in Lawrence to Mr. Ordway, of Manchester, N. H."

In Ehrenberg's *Mikrogeologie*, T. XXXV, A. VI, is represented a deposit of diatomaceæ said to come from Perth, N. H. [?], and this is mentioned as described in the *Transactions of the Berlin Academy* for 1843. In the same work, T. XXXIII, X, is represented another similar deposit from New Hampshire,—more particular locality not being mentioned. This is said to be described in the *Transactions of the Berlin Academy* for 1845. This work is not accessible to me at the present time; therefore I am unable to give the particulars mentioned by Ehrenberg concerning them.

These, then, constitute all of the material I possess up to the present time representing the diatomaceæ of the state of New Hampshire, and as soon as I shall be able to work up the forms contained in them I will transmit you a full report thereon. In the meantime it is extremely desirable that we should receive recent collections from other parts of the state; and I would particularly call attention to the fact that we have not, as yet, received any gatherings from brackish or salt-water. Specimens of marine algæ encrusted with diatomaceæ, as they almost always are, would be particularly acceptable. Respectfully yours,

A. MEAD EDWARDS, M. D.

NEWARK, N. J., September 1, 1874.

Prof. C. H. HITCHCOCK, State Geologist:

Dear Sir—I have thought that it might prove of interest to students of the Desmidiæ to know that while making collections of diatomaceæ in and around Han-

over, N. H., in the summer of 1871, I procured the following species belonging to that family:

Didymoprium Borreri.

Desmidium Swartzii.

Microsterias denticulata; *Microsterias crenata.*

Cosmarium Botrytis.

Staurastrum polymorphum.

Docidium nodulosum.

Closterium angustatum.

Pediastrum Boryanum.

As special gatherings for obtaining these organisms were not made, the above list is very brief; but hereafter I hope to add to it, as the desmidiæ of the United States have not been much studied, and a great deal remains to be done in our micro-zoölogy and micro-phytology. Respectfully yours,

A. MEAD EDWARDS, M. D.

NEWARK, N. J., September 1, 1874.

Prof. C. H. HITCHCOCK, State Geologist:

Dear Sir—During my excursions in and around Hanover, N. H., three years since, in search of diatomaceæ, I collected a few specimens of wild plants infested with diseases caused by the growth upon them and in their tissues of microscopic parasitic fungi. These I submitted to my friend, Mr. M. C. Cooke, of London, Eng., the well known fungologist, and he was so good as to identify them. They were the following:

Æcidium Violæ, Schum., on wild violet. *Viola.*

Æcidium grossulariæ, D. C., on wild gooseberry. *Ribes hirtellum.*

Æcidium Dracontii, Schw., on Indian turnip. *Arum triphyllum.*

Æcidium asterum, Schw., on a plant whose name was not ascertained.

The mere announcement of the discovery of these species in New Hampshire will not perhaps prove of interest to the majority of the readers of the survey report; and this will arise from the fact that they will not be sufficiently informed with regard to the important bearing these minute plants have upon the occupation of the agriculturist. There is no doubt that it would be greatly to the advantage of the farmer were he better informed concerning both the animals and vegetables which prey upon his crops. If he knew something of their habits and modes of attack, he would be the better prepared to resist their depredations, or even to attack them in such a way as to preserve his crops, and thus save for himself much money and labor. At some future time, and as further specimens come into my hands, I shall take the opportunity of transmitting to you some remarks on the fungi injurious to the crops of the agriculturist. In the mean time, students of these plants may be glad to know that those I mention have been found in New Hampshire.

Respectfully yours, A. MEAD EDWARDS, M. D.

CHAPTER XV.

PHYSICAL HISTORY OF NEW HAMPSHIRE.

WHEN the geological structure of a territory is well understood, it may be interesting to review the changes that have taken place in respect to its physical dimensions,—beginning with the reclamation of the first foot of dry land from beneath the level of the ocean, and continuing the sketch with a description of the variation in its outlines, whether an enlargement or contraction. Besides the increase and decrease of territory, physical history may embrace a notice of the origin and arrangement of the mountain ranges intermittently arising to view, changes in the character of strata brought about during a period of elevation, the adaptations of the successive land-surfaces to the existence of life, and other related topics.

The subject is a novel one, as very few laborers have wrought in this field. Our conclusions have been drawn entirely from the induction of facts obtained by observation, and not from a comparison of theories propounded by eminent physicists. Our views did not spring into being fully developed. At first only a glimmering of the truth appeared; by and by the light was like that of the dawn of day; then the skies became brighter and brighter;—but I will not presume to say that the truth is now so manifest that no more information is required to make the history perfectly known. The maps illustrating the successive shapes of our territory may require modification, in consequence of a better knowledge of the distribution of the several formations. There is much

to be discovered yet in the southern part of the state. Some of this information will be obtained for our final geological map. If the reader finds discrepancies, he may accept the conclusions last stated as the most authoritative.

This sketch is really an epitome of the geology of the state. It presupposes the establishment of the entire geological column, the order of the formations, and their geographical arrangement upon the map. If correct, it assumes the solution of questions which have agitated geological circles for forty years. We can only refer to the next volume for the establishment of all these fundamental doctrines, and will state the subject as if they were thoroughly proved.

It is not desirable to go further back in time than to the period of the deposition of the first rock formation in the state. There are interesting speculations respecting the history of our planet, for ages anterior to its solidification. It may have formed part of a nebula comprising first the entire solar system, and afterwards only the earth-mass. In later times it is thought to have existed in the condition of igneous fluidity. A long series of ages may have been occupied in the changes which effected the formation of a solid crust, the falling of the steam and vapors in the atmosphere to form a saline ocean, and the separation of elevated and depressed areas from each other to allow of the erosion of rock and deposition of material in the lower portions. During much of this time the special area now known as New Hampshire could not be distinguished from the adjoining territory. It will therefore be best to confine our studies to the time when dry land began to appear within our borders, and then describe the successive eras of growth as truthfully as possible.

At this point it is important to state the terminology of our science. Human history is divided into periods, according to the supremacy of various nations or prominent ideas. Geological history is classified in accordance with the succession of life, and the predominance of particular classes. Four groups are recognized. 1. EOZOIC, or the period of the introduction or *dawn* of life. 2. PALEOZOIC, or the time when *ancient* types of life predominated. 3. MESOZOIC, or the time when the *middle* types of life prevailed. 4. CENOZOIC, the latest period, when all will recognize the *recent* character of the organisms.

Of these great eras, New Hampshire furnishes quite fully the formations accumulated during the first, and somewhat of the second. After that, there are hints as to her condition derived from general considerations, which will be mentioned in the proper place. The Eozoic era is divided into the Laurentian, Atlantic, Labrador, and Huronian periods in New Hampshire.

The following considerations lead us to believe that life existed in these periods.

1. The presence of ores of iron is an evidence of the existence of vegetation. Ores of iron are conceived to have been formed similarly in all ages. At the present day they accumulate in swamps and low grounds in the form of bog ore, or the hydrated peroxide (ferric). To effect this deposition the presence of organic matter is requisite. The iron is present in the soil in small proportion, as the insoluble ferric oxide. Vegetation, when soaked in water, imparts to it the capacity of dissolving this ferric oxide. A portion of the oxygen is given off, and the compound becomes the ferrous oxide, and in this condition is readily soluble. But this is not a stable compound in the presence of the atmosphere. There are new combinations, and the soluble ferrous, or protoxide, is changed to the insoluble hydrated peroxide, and is precipitated, falling to the bottom. This process being continued indefinitely, there accumulates a large thickness of the bog ore, oftentimes sufficient to furnish material for the smelter.

It is supposed that most of the ores of iron in every age have been formed in this way. As the modern bog is now essential to their production, so must there have been vegetation in the most ancient periods to eliminate the iron.

Furthermore, the Laurentian vegetation must have been extremely abundant, on account of the enormous deposits of iron ores seen in the Adirondacks, Ontario, Missouri, etc. There are beds hundreds of feet in thickness. This proof is afforded by certain beds in New Hampshire, as in Lisbon (Franconia) and Landaff. The beds in Bartlett and Gilford are in granite, and may possibly have come from igneous action, and if so are likely to be limited in quantity.

Chemical changes have taken place in the original bog ore in order to produce the magnetic ore of Lisbon. This is two-fold. First, the water

has been expelled, perhaps by the action of heat. This would give rise to hematite and specular iron, which differ from the original compound only by the absence of water. Second, a further change, probably the continued application of heat, expels a part of the oxygen, producing the magnetic oxide,—a compound intermediate between the ferrous and ferric oxides in respect to the amount of oxygen present.

The preparation of the quartz of Lyndeborough for the manufacture of glass illustrates the nature of the chemical changes which I have just mentioned. The quartz as taken from the ledge is not perfectly pure, since it contains a small per cent. of ferric oxide, perhaps combined with water. This colors green the vessels manufactured from it, and therefore it is best to eliminate the iron as completely as possible, so as to secure a better quality of glass. The rock is put into a kiln and burnt, just as if it were limestone being converted into lime. The rock becomes friable, so that it can be readily crushed and pulverized, and the iron is converted into the magnetic oxide. After pulverization, the quartz-flour is made to fall in a stream over magnets set like bristles on the surface of cylinders. The magnets instantly attract the iron sand, which is thus perfectly removed from the quartz by several repetitions of the process of falling over the revolving cylinder. Had not the fire removed the water and a portion of the oxygen from the iron ore, the magnets could not purify the quartz. The change is precisely like that which has taken place in the magnetization of the Laurentian ore-beds, and hence it is reasonable to suppose that nature has done the same work upon a large scale which may be often witnessed at the Lyndeborough glass-works.

2. The presence of graphite, plumbago or black-lead in the Eozoic rocks is evidence of the former existence of vegetation. We do not yet know how to account for the existence of graphite in the earth, except through plants. Great changes have been effected in its mass, so as to have entirely altered its nature. Instead of being combustible, it is one of the most refractory substances known, and is largely used for the manufacture of crucibles in which metals are fused. No one has yet detected any traces of vegetable structure in graphite, so that we have no evidence from morphology of the nature of the earliest plants. From general considerations, we may believe them to have been algæ, fungi, or lichens, perhaps, of giant forms and of particular shapes not represented

in living nature. Our rocks afford graphite in abundance, and hence suggest the presence of plants in New Hampshire in the earlier periods.

3. Some argue the presence of animal life in the older rocks, on account of the presence in them of limestone. It is said that all limestone found in stratified rocks has been derived from the decay of the shells of marine animals or other organisms. If this be true, it is certain that organisms once flourished in our state, as we have an abundance of Eozoic limestone in Lisbon, Haverhill, Amherst, etc. The argument is not a strong one, since many thermal waters are constantly depositing tufa, oftentimes in massive beds.

4. Animal life is thought to have been abundant, because of the presence of the *Eozoön* in the Laurentian of New York, Massachusetts, Ontario, and elsewhere. In 1858, J. McMullen, an explorer attached to the geological survey of Canada, brought specimens from the Laurentian limestones of Ontario to Sir W. E. Logan, the director of the survey, which had an organic appearance. The first examinations did not reveal anything like organic remains, though Sir William believed they must be the relics of life. They were exhibited to the geologists at the Springfield meeting of the American Association for the Advancement of Science, in 1859. In February, 1865, a series of papers appeared in the *Quarterly Journal of the Geological Society of London*, by Sir W. E. Logan, Dr. J. W. Dawson, Dr. W. B. Carpenter, and T. Sterry Hunt, wherein arguments were set forth in favor of the foraminiferal character of the supposed organisms, to which the name of Eozoön Canadense was given by Dr. Dawson. This proposal called out investigations in various quarters,—some in favor of the Canadian theory, and others in opposition to it. Those best acquainted with the recent forms of the foraminifera usually believe that this Eozoön is of organic origin; those who disbelieve the organic theory are mostly better skilled in mineralogy than biology. The discussion is still warmly pressed; and it is not judicious to quote the existence of this possible organism as satisfactory proof of the presence of animal life in the Laurentian. The author, however, is satisfied with the arguments urged in favor of its organic nature;—the more readily, since two of the considerations previously stated afford a substantial basis for the existence of plant-life during the same early period.

The terms *Azoic, without life*, and *Hypozoic, beneath life*, are still applicable to the stratigraphical systems which flourished antecedently to the Laurentian, but they are not appropriate designations for any of the crystalline strata which are now referred to the Eozoic. If it be objected that many will still understand these terms in their former acceptation, it may be answered, that, when properly informed, such persons will more easily understand the shifting of the designation than the proposal of a new name. For the past twenty-five years many groups of strata had been removed from the Azoic system without giving rise to any misunderstanding. Furthermore, no one is yet able to point to any locality where these most ancient systems crop out; hence the liability to misconception is greatly reduced. The Azoic rocks, as now understood, are limited at their top by the Laurentian system, and at the bottom by the very beginning of deposition. If we grant the existence of animals in the Laurentian, and follow out the analogies derived from the development of the higher from the lower forms of life,—animals succeeding plants,—then there must have been an immensely long period antecedent to the Laurentian, characterized as the Eophytic, or the dawn of plant-life. This system, if ever discovered, will be entitled to a place by the side of the four great divisions specified above.

The name Eozoic seems to have been proposed by Dr. J. W. Dawson, of Montreal, in 1865. He did not fully define the limits of its application at that time; but it seems to have been generally understood by geologists to embrace all the obscurely fossiliferous rocks older than the Cambrian. The considerations just stated, showing that our crystalline rocks contain obscure evidences of life, make it plain that the Eozoic system is a natural one, characterized by very scanty traces of organisms. Its separation, as a system, from those beneath entirely devoid of life, is also natural, and in accordance with the most approved geological usage.*

THE FIRST DRY LAND IN NEW HAMPSHIRE.

Accepting as a fact the doctrine that the whole globe was entirely covered over by the ocean before the beginning of the deposition of

* The recent proposal by Prof. J. D. Dana, in the second edition of his Manual of Geology, to call both the Azoic and Eozoic systems *Archæan, the beginning rocks*, seems uncalled for, but would be less objectionable if the author's own definition was strictly adhered to. The distinctions given between the Azoic and Eozoic are not incompatible with those stated in the text above; but the word *Archæan* is nearly universally used in the sense of *Eozoic* throughout the Manual. On page 140, in giving the subdivisions of all geological time, he says,—"ARCHÆAN TIME, including an Azoic and an Eozoic era, though not yet distinguished in the rocks. 1. Azoic Age. 2. Eozoic Age." On page 148, reference is made to Dawson's suggestion of the word Eozoic in place of Azoic, with the opinion that its use is objectionable, because the supposed Eozoön may be of mineral nature. On page 151, the *Archæan Era* is divided into the two periods, Laurentian and Huronian. The word Archæan, on page 151, seems to be synonymous with Eozoic, on page 140. I do not suppose the use of the word Eozoic implies belief in the existence of the animal Eozoön. The adjective to be used in that sense would be *Eozoönal*. The distinction between the true Azoic and Eozoic ages is of greater import than between any other two of those used to mark geological time; and hence the union of them under one designation is uncalled for. Furthermore, Dawson's name has the advantage of several years' prior suggestion and general usage among geologists. It is also undesirable to break up the unity of the terminology of the great ages of the world's history by adopting a term not having the termination of zoic. For these and other reasons, it does not seem to be for the good of the science to substitute Archæan for Eozoic in geological literature.

sediments, we look in vain over the broad expanse of waters for any landmark to indicate the boundaries of New Hampshire or the neighboring states. Towards the close of this epoch, and probably after the formation of large islands to the north in Canada, and to the west in New York (Adirondack region), oceanic currents began to accumulate sediments in the shallower places. After a while these masses attained large dimensions; and the operation of igneous forces beneath brought to the surface an archipelago of islands, perhaps thirty in number. These constituted the first areas of dry land in New Hampshire. The position and shapes of these islands, as the rock composing them now crops out, are shown in the first of our series of illustrations.

These islands were probably composed of clay and sand. The clay may have come from the decomposition of still earlier feldspathic rocks, possibly the original crust of the earth. The sand may have been washed from some of the primeval piles of superfluous silica, which found no congenial element with which to unite in the world-making process. As these areas are now examined, they seem to be composed chiefly of porphyritic granite or gneiss, which, to ordinary eyes, appear to be very unlike clay and sand. Is it possible that the sediments have been altered into these crystalline aggregates?

The answer to this question involves propositions the most difficult of any in our science to be lucidly explained. It is only sufficient now to state our theory. These primeval deposits of sand and clay, by the action of steam, heat, and chemical agents, have been changed into gneiss and granite. The large crystals of feldspar and the scales of mica are the products of the alteration of clay. The sediments are supposed to have been rendered soft and plastic through heat and steam; and chemical affinities have collected together, from a heterogeneous mass, all the elements required to form the two crystalline minerals. After their crystallization, the residuum, consisting of amorphous silica, sought the crevices between the newly formed minerals, became closely packed because of a considerable pressure crowding the mass, and have had no opportunity of assuming the geometrical shapes forming when the quartz is situated in favorable situations. This change is known as *metamorphism*.

The resultant rock attracts attention by its spotted appearance. One

THE FIRST DRY LAND
IN
NEW HAMPSHIRE
No. 1.
Areas of Porphyritic Gneiss, constituting islands.

of the finest exposures of it lies in the towns of New Hampton and Meredith. At Lake Village it is the most common stone used for underpinning. Along the Boston, Concord & Montreal Railroad, from Ashland to Lake Village, ledges of it are frequent; also, along the Northern Railroad, between West Andover and East Canaan. The rock is grayish, rarely dark brown, with rectangular spots thickly scattered over it varying in size from one fourth of one to two or three inches long, and a fourth part as wide. These crystals of feldspar are sometimes arranged in lines, their longer axes being parallel one to another, or they may be thrown together indiscriminately. This difference in arrangement indicates, perhaps, the degree of intensity with which heat has acted upon the rock. The first are akin to strata of gneiss; the second is a granite, resulting from the aqueo-igneous fusion of the first. The fusion must have been protracted and the material very plastic, in order to permit the development of such large and abundant crystals.

It is probable that some of these islands were united at this first time of elevation, though they are now separated by other material of later origin, formed partly from the degradation of the former, and deposited upon it. There has been much crowding of the older rocks in subsequent periods, so as to compress what may have been a large island at first into an insignificant patch. It would not be surprising if this archipelago originally covered as much area as the two states of New Hampshire and Vermont combined. Our representation must therefore fall somewhat below actual truth. The widest stretch of the imagination can mark out a possible arrangement of these primeval areas, but it would not satisfy the mind so well as the delineation of their present limits. With this explanation presented, the reader may conceive the separation of these areas over a greater range of longitude than is permissible within the present state limits. There would not be much variation in the length, as the crowding in later times came from the east or west.

This archipelago must have been considerably isolated from every other existing territory in this ancient period, since we must go a long way in any direction to find the same formation. It is entirely unknown in Vermont, but crops out in the Adirondacks, and north of the St. Lawrence, in Canada. Very little is known of the rocks in western Maine, so that it cannot positively be said to be wanting there, though I have

discovered no traces of this formation west of Prospect and Frankfort, on the Penobscot river, except near Mt. Bigelow. East of the Penobscot it is as abundant as in New Hampshire. Southerly the formation probably extends through Massachusetts into Connecticut, along the western portion of Worcester county.

It would appear, therefore, that in New Hampshire and Massachusetts, at the close of the first great period, there was a long sandy ridge, corresponding to the distribution of the porphyritic granite, while, along the Green Mountains and in western Maine, the ocean concealed everything from view. It is likely that there is now, beneath the intervening strata, a continuous sheet of this porphyritic rock connecting the New York, New Hampshire, and Maine outcrops, which, in the early era, constituted the bottom of the ocean. Dredging machines would have found nothing all over this floor different from the porphyritic sediment.

A study of the map will show a few matters of interest in respect to the distribution of this formation: First, no land existed thus early north of Whitefield. Second, there are two principal ranges. The most important commences in Whitefield, runs to Franconia, Moosilauke (not the summit), Groton, Mt. Cardigan, Grafton, and so on continuously to Jaffrey, and probably is the same with the Chesterfield and Winchester island. The next starts from the south base of Mt. Carrigain, east of Lincoln, is strongly developed in Waterville, Sandwich, New Hampton, Meredith, etc., and follows the south-west border of Lake Winnipiseogee into New Durham. Third, this lake range is remarkable for its curvatures. Proceeding southerly, it makes a sharp turn in New Hampton, runs back northerly to Squam lake, and then folds back on itself like the barb of a fish-hook, and assumes a south-easterly course (p. 55). Before discovering the fact of these curvatures, I had erroneously represented the Waterville range as continuous to Dublin. Fourth, the principal range lies along the line of greatest elevation in the state (pp. 210, 211), or the water-shed between the Connecticut and Merrimack rivers. The most northern area attains the altitude of about 1600 feet, the lowest part being about 1000 feet. The Franconia-Rumney area shows the rock as high as 4300 feet. The higher points are Lake of the Clouds, Mt. Lafayette, over 4000 feet; Mt. Kinsman, 4300; Blue ridge, 2000; hills in Ellsworth and Rumney, probably 1800 feet.

The Groton-Jaffrey range gives us Mt. Cardigan, 3156 feet; hills in Grafton, nearly 2000; line of railroad from West Andover to Grafton, 677 to about 900; Mt. Sunapee, 2683; Mt. Lovell, 2487. The southern end of the area is more than 1000 feet above the sea. Fifth, there is a group of islands in Warner, Salisbury, Webster, Hopkinton, and Henniker, connected with the end of a promontory trending north-easterly from the main range at Hillsborough. Sixth, a conspicuous line of islands reaches from the north part of Webster, through Hopkinton and Weare, into New Boston, over twenty miles long, and curved like a bow. Seventh, possibly the Pelham and Seabrook islands, represented on north-east range along the Massachusetts border. Eighth, it is noticeable that the northern ends of the principal ranges sink beneath the higher White Mountains, and have not yet been discovered to the north of them in New Hampshire, though appearing east of Mt. Bigelow in Maine,* ninety miles or more north-easterly from Mt. Carrigain.

Additions during the Atlantic Period.

At the close of the Atlantic Period the area of dry land was very considerable, occupying fully two thirds of the present state limits. In general terms, this area may be said to be central, the portions not filled out being at the extreme north, on the sea coast, and along the Connecticut valley. The flanks of the principal porphyritic formation are covered, and much of the space between the primitive islands is filled up. The rock is also very commonly a gneiss.

Several important events are indicated by the succession of deposits. I give them as seems in best agreement with the facts as now understood. First, and lowest down, are rather local deposits of a somewhat talcose gneiss, receiving the name of *Bethlehem group*, from the locality where its features are best displayed. Second, *Winnipiseogee lake* (or, for short, *Lake gneiss)*. I think this includes the Berlin and Manchester ranges, mentioned in some previous publications. Third, *Montalban*, or *White Mountain series*. Fourth, *Franconia breccia group*. It is not needful to distinguish these formations on the map at present, and the second of our map-illustrations merely shows the whole system as it stands related to the preceding areas.

* *Proc. Amer. Ass. Adv. Sci.*, vol. xxii, p. 212.

Several features of this distribution are interesting. First, the rocks have a general north-east south-west course. Second, they occupy the spaces adjacent to and between the first areas of dry land, just as we should naturally expect if the additions have been made to nuclei. A more careful study of the arrangement shows that the same succession of formations is observed in traversing either flank of the porphyritic group. The same member touches both sides of the porphyritic area; the second lies adjacent to the first in each direction; the third is alongside the second, connecting laterally,—and so on. Third, there are several smaller areas of this age in the neighborhood. One occupies Odell and vicinity. Another ranges through Essex county, Vt., and probably exists as an underground ridge from Concord, Vt., to Reading, Vt., where it seems to reappear and extend nearly to Massachusetts along the same course. Small areas are situated about Bellows Falls and Pelham. Another of great importance is the Green Mountain gneiss of Vermont. The main range of New Hampshire stops short of the Kennebec river, in a north-easterly direction, but seems to reappear on the south-east in an extensive area between York and Hancock counties in Maine. Fourth, this formation occupied several areas at the close of the Atlantic age, which were concealed by the deposits of later eras. Such are the Pemigewasset district at the White Mountains, and considerable parts of Carroll, Strafford, and Merrimack counties. It is to be presumed, also, that the most distant areas, as the Green Mountains, and coast of Maine districts, are connected directly with the New Hampshire deposits by a sheet of sediments which bend down deeply into the earth, directly overlying the porphyritic gneisses of the first period. The space between the White and Green Mountains might then be regarded as a great basin, or synclinal, held up by the porphyritic cup, and itself sustaining various newer sheets of rock. Fifth, the general height of the Atlantic rocks corresponds well with the average elevation of the state above tide-water, except,—Sixth, the Mt. Washington range from the Saco valley to Mt. Bigelow in Maine. Its greater height is probably due to additional elevations in later periods, while there is reason to believe that it was raised to an unusual height at this time.

Considered historically, the following notable events occurred during the Atlantic period: 1. There was a deposition of sediments between


NEW HAMPSHIRE
AT THE CLOSE OF THE
ATLANTIC
OR
GNEISSIC PERIOD
No. 2.
EXPLANATION.
ATLANTIC Group, including Porphyritic Gneiss.

Berlin and Lebanon, chiefly in the Connecticut valley and in Carroll county, of sandy grits, which we know in the altered state as the *Bethlehem group*. 2. It is likely that these strata were elevated and metamorphosed at the close of this era. 3. The very extensive deposits of the *Lake gneiss formation* were next laid down. The largest amount of them underlie the hydrographic basin of Winnipiseogee lake, and follow the porphyritic band south-westerly towards Peterborough. The same group extends from southern Cheshire county, through Sullivan and Grafton counties, to Milan, and also from Mason to Deerfield, through Manchester. 4. Nearly all the rest of the Atlantic area, or the *Montalban group*, was next deposited. The rocks are of two or three kinds. There is a gneiss, largely deficient in feldspar, containing crystals of andalusite in abundance. This characterizes the principal White Mountain summits. A second variety is excessively ferruginous upon decomposition. A third is the well known "granite" of Concord, Plymouth, Farmington, Milford, Fitzwilliam, Troy, Marlborough, etc. It is really a stratified rock, whose divisional planes can be detected only with great difficulty. There must have been variations in the conditions of deposit to insure the accumulation of sediments that should alter into schists so diverse from each other as these. 5. Next came the ejection of the granitic mass, giving rise to the Franconia breccia. This igneous rock is completely filled with masses of all the formations that have been described thus far, but carries none of those that succeed. Hence it seems to have been connected with the great series of disturbances closing the long period of quiet Atlantic deposition. This rock covers a few square miles in Franconia, and may be repeated in Granby, Vt., and possibly at one or two places along the Connecticut valley. The paste of the breccia is mostly feldspathic in its mineral constitution. 6. Next came probably the greatest period of disturbance and elevation known in the whole history of New Hampshire. The White and Green mountains came into being, and, most likely, the whole system of Atlantic mountains, from Canada to Alabama. They may not have assumed their present elevation at this time, but became a marked feature in the primeval landscape, and prominent objects for the action of the atmospheric elements, breaking down and washing away all jutting out points. In connection with the elevation, the sedimentary strata became converted into crystalline schists.

This grand event closed the Atlantic period. Its importance demands some further notice of the action of the forces producing elevation, and the process of metamorphism.

The Elevating Forces.

Many persons think a mountain is elevated by some force or agent situated directly underneath, and that the thrust is upwards, and the mass of matter retained in place by an injection of molten matter. It is difficult to comprehend how any such action can have taken place on a large scale; and hence we must avail ourselves of quite a different theory. Its general application can be perfectly understood by reference to an action common in the winter throughout the Northern states.

When snow covers the ground, it is easy to push it away from a given area; but a ridge is built up just on the edge of the cleared walk. Suppose our assistant takes a pole, fastens it into the centre of a piece of board, one foot high and three feet long. A single effort will enable him to clear a space three feet wide by pushing the board away from him. If three hundred men, each armed with a similar snow-pusher, should act simultaneously along a sidewalk nine hundred feet long, there would suddenly start into being a ridge of snow nine hundred feet in length. The force of elevation in this case is a lateral one, and it accomplishes the same result as if some power had acted upwards from beneath along the same line. Now our theory supposes the existence of a mighty force acting laterally along the whole length of the Atlantic formation, from Canada to Alabama, in the same way that the ridge of snow was elevated. The power displayed is great enough to shove along the thick, horizontal sheet of sediments; and, where the substratum is firm, to fold up a mountain range resting upon durable foundations. In case the floor is yielding alongside of the range, a valley would be formed parallel with the mountain. If the foundation is unyielding, there will still naturally be depressions or valleys between the mountain ranges.

The origin of this lateral force is suggested by certain geological features of our vicinity, and general theoretical considerations. 1. Given the existence of the parallel older ridges of the Penobscot district in Maine, the primeval archipelago in New Hampshire, and the Adirondack hills in New York, and grant that some energy causes them to

approach each other, we can see that the Atlantic schists between would be crowded by lateral forces so as to produce mountains, if the pressure be sufficiently great. It would not be easy in this case to say that the force came from the south-east or from the north-west, but practically from both quarters. If the Profile-Sunapee porphyritic range were moved north-westerly, it might not be more influential in folding up the Green Mountains than the Adirondacks, since their power of resistance is practically an energy pushing in the opposite direction. It has been common among geologists to argue that the pressure inducing elevation in North America has come mainly from the south-east, or from the ocean towards the interior; but in the present case there is certainly reason to believe that the force has come as much from one as from the other quarter. 2. Accepting the doctrine of the earth's refrigeration from the condition of igneous fluidity, it is easy to understand why parallel ridges should be made to approximate to each other, and consequently in their motion crumple up the thick rock masses lying between them. In cooling, a crust forms over an igneous interior. This crust eventually becomes so large that it cannot fit the nucleus within it, and hence there must be a bending of the stiff envelope to bring the two parts together. The crust cannot possibly fit the interior save by sinking down almost everywhere, and rising along a few lines, so as to make ridges on the surface. The process of shrinkage and ridging by the close of the Atlantic period may be supposed to have been carried on so far that the three parallel lines of land just spoken of correspond to three elevated lines on the surface of the earth's crust. The process of cooling had been going on for an immense period; the interior is ready to fall away from the stiff envelope; the sinking of several hundred thousand square miles of surface takes place. Consequently the older ridges are forced nearer together, and as they move towards each other the intervening horizontal Atlantic rocks are mercilessly crumpled up, folded, and broken. As the force exerted is irresistible, the two prominent Mt. Washington and Green Mountain ranges are crowded up so as to become conspicuous elevations.*

* It is sufficient for our present purpose to refer the origin of the Atlantic mountains to a lateral pressure produced in connection with the shrinkage of the earth's crust. There are a multitude of considerations which ought to be presented in order to elucidate the subject properly. I propose to devote an entire chapter to the statement of a proper theory of the elevation of mountains, with abundant historical references,

The Process of Metamorphism.

The alteration of the rocks is intimately connected with the elevation of mountains and continents. The agents which caused the land to bulge upwards also induced the conditions favorable to metamorphism. Crystalline rocks abound in regions of disturbance, and are mostly wanting where subterranean influences have not been liberated through dislocations and crumpling.

The problem awaiting solution is this: How can the original heterogeneous mixtures of clay, sand, and gravel become arranged into essentially homogeneous layers of crystalline schists of gneiss, Concord granite, ferruginous and andalusite rocks? There is no superficial resemblance between river sand and Concord granite;—what is the process by which the latter can be evolved from the former?

In reply, we must assume the identity in mineral composition between the original and derived masses, save in these few cases where evidence of the withdrawal of one and the substitution of another ingredient can be rendered probable. Granting this point, we have simply to show that the sedimentary beds have been subjected to conditions suitable for the action of elective affinities among the atoms.

If aggregations of minerals are exposed to great heat, so as to be reduced to the melted state, the conditions would be favorable for the action of elective affinities, and new compounds would result. Whenever this experiment is tried, the results agree with our expectations. Whoever examines the slag of a furnace, or the lava freshly ejected from a crater, will find many crystals scattered in geodic cavities throughout the material that has been melted. The elements have been redistributed into new compounds, because the conditions were favorable to their transposition and recombination.

But the heat required for the melting of solids is more than sufficient for the simple metamorphism of strata. It may be that certain eruptive granites have come from the absolute melting of strata; but the schists of the Atlantic gneiss have not lost their stratification. If the original

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giving credit to those who have made important suggestions towards the true explanation of the process. This essay must be deferred to the next volume, because the present one is already sufficiently large to be conveniently handled. Extensive reference to metamorphism is also deferred for the same reason.

heterogeneous deposits possessed peculiar chemical characters, they still remain. There has been chemical action in the midst of the particles of each stratum. The atoms have been perfectly free to move about and enter into new combinations. And it is easy to understand what conditions may insure these results. If the rocks are charged with hot water or steam, they will assume a considerable plasticity, and the atoms will be free to move in all directions, perhaps confined by the walls of particular strata. Other conditions favor the chemical reactions. Great pressure gives energy to the action, and there is an abundance of time allowed for the completion of the work. In a furnace the fire is removed, and the minerals have very little time to crystallize out. But the metamorphic action may continue for hundreds or thousands of years without diminution. It is this long continued constant agency which accomplishes in the end as much as a more thorough melting in a short time.

The conditions favorable for the metamorphism of rocks are developed during periods of elevation. 1. The motion of shoving along the strata is converted into heat. 2. When this force has crushed rocks, an immense amount of heat has been liberated, enough to melt entirely the mashed material. 3. Elevating forces are connected with displays of subterranean heat. When strata are broken, immensely large fissures are made, which extend down to igneous masses below the crust, not necessarily a melted interior, but large reservoirs, comparable with oceans for size. Compression may bring portions of this igneous material to the surface through the fault, or at least send up strong thermal influences. All these combined are sufficient to produce metamorphic changes.

The facts of plication and disturbance are everywhere evident in the Atlantic rocks, so that, whether we fully understand the process or not, it is clear that the formation has been subjected to influences capable of rendering them plastic, and thus of allowing chemical changes.

As to the character of the original strata, it is likely that they were all derived from the older porphyritic strata by the action of currents of water of different velocities. The ordinary gneisses correspond with the average composition of the older rock, and may have resulted from their disintegration, the newer strata being argillaceous sandstones. The ferruginous rock is fully four fifths silica, and its origin may be ascribed to those currents which were fitted to transport finely divided silica. As

the ferruginous appearance results from the decomposition of iron pyrites, it is perhaps reasonable to look to the waters of the ocean for the small percentage of sulphur required to combine with the iron of the mud. This may have been reduced from sulphates in the water through the agency of organic matter. The andalusite rocks were probably very clayey, deficient in alkali. This clay might result from the decomposition of feldspar. As the removal of potash and soda from feldspar is the prerequisite for its disintegration, the resulting clays might be deficient in the alkalies. After metamorphism we should therefore expect the production of schists corresponding in mineral composition, or with the predominance of silicates of alumina without an alkali, like andalusite, fibrolite, staurolite, and kyanite. These schists do not usually contain a large proportion of feldspar.

The Concord granite would probably come from argillaceous sandstones, the silica being rather meagre in amount. This division has probably been subjected to peculiar influences, so as to induce the compact, even structure of the rock. The appearances would indicate a long continued quiet metamorphic action, which has reduced the minerals to a uniformly fine texture. The rock is evidently the equivalent of the celebrated Monson, Mass., stone, where the layers of deposition are as evident as in a freshly excavated hill of sand. It would seem as if the action in the latter case had been retarded before the conversion of the material into so homogeneous a mass.

More than one period of metamorphism seems to be indicated by the facts. The Franconia breccia holds in its embrace fragments of metamorphic rocks of all the varieties that are peculiar to the Atlantic system in that part of the state. The original formations must therefore have all been altered prior to the production of the breccia. Possibly this rock belongs to the following period, but it was as certainly prior to that, as it clearly followed the Atlantic age. Hence I have regarded it as marking the transition between these two great eras.

Use of the terms Atlantic and Montalban.

Those who have read the annual reports will observe that this is the first occasion in which I have used the term *Atlantic*. My first report, printed in 1869, proposes the name of White Mountain series for all the gneissic rocks east of the staurolite rock in Lisbon (see page 17 of this volume). In 1870, Dr. T. Sterry Hunt wrote a letter to Prof.

Dana upon the geology of eastern New England, published in the *American Journal of Science*, II, vol. L, p. 83, in which he includes the rocks of the White Mountains with a group in Nova Scotia recently investigated by Mr. Murray, and stated to contain "soft bluish-grey mica slates and micaceous limestones, belonging to the Potsdam group; besides a great mass of whitish granitoid mica slates, whose relation to the Potsdam is still uncertain. To the whole of these we may perhaps give the provisional name of the *Terranovan series*, in allusion to the name Newfoundland." This series is definitely stated to lie "between the Laurentian and the Quebec group."

Next, Dr. Hunt describes rocks of similar characters on the St. Croix, N. B., and in Nova Scotia. He says of the latter,—"These include mica schists with chiastolite and garnet, and appear identical with those already observed by Dr. Dawson in other parts of Nova Scotia, which I had already recognized as the same with those of the White Mountains, and those of the St. Croix." He says further of the same,—"which I believe to belong, like those of the St. Croix and the St. John rivers, to the great Terranovan series. The micaceous and hornblendic schists, with interstratified fine grained white gneisses (locally known as granites) which I have seen in Hallowell, Augusta, Brunswick, and Westbrook, in Maine, appear to belong to the same series, which will also probably include much of the gneiss and mica schist of eastern New England." Of another region he says, in the same letter,—"I believe, however, that much of the calcareous mica slate of eastern Vermont will be found to belong to the Terranovan series."

From these quotations I think it plain that the author is inclined to believe that the rocks of the White Mountains, together with the micaceous staurolitic rocks of eastern Vermont, belong to one system, which is styled the Terranovan. As certainly a part of this is stated to belong to the Potsdam, I should infer that the author believed the Terranovan series to have been deposited about the time of the Potsdam or Cambrian period.

In 1870, my second annual report (page 26 of this volume) amplifies the definition of the White Mountain series, making it to include everything now referred to the Atlantic system, and, also, the porphyritic granite. The name of Coös group was applied in the second report to a set of rocks along Connecticut river, that had been marked in 1869, upon a published map, as distinct from the White Mountain series. This report was prepared immediately after the reading of Dr. Hunt's letter, referred to above, in manuscript; and the two documents were printed about the same time. I gave the name under the impression that the group represented by it corresponded to the Terranovan series of Newfoundland, and was nearly of Cambrian age; but, as distinctly shown in the reports for 1869 and 1870, I separated the Coös from the White Mountain series, the latter being regarded as pre-Cambrian.

In 1871, Dr. Hunt delivered a very able and carefully prepared address before the American Association for the Advancement of Science, in which he distinguished between the gneiss of the Adirondacks, the quartzo-feldspathic rocks of central Vermont (improperly termed the "Green Mountain series," since the rocks of the Green

Mountain axis, both in Vermont and for a considerable distance into Canada, are the same with the White Mountain series), and the White Mountain series. This address seems to be the first place where the author uses the term White Mountain series to apply to a system of rocks, and he evidently intends that it shall take the place of the name of Terranovan (p. 33). Dr. Hunt, in this address, clearly states that he believes this series of rocks to be both pre-Silurian and pre-Cambrian in age; and I owe him an apology for quoting him, on one occasion, as having called them Cambrian in this address. My only excuse is the impression derived from his letter of the previous year, that he considered the White Mountain series the equivalent of the rocks in Newfoundland carrying Potsdam fossils, and my inability to be present during the delivery of the Indianapolis address.

It will be observed that the definition of White Mountain series, given in this address, corresponds with mine of the previous year, even to including the porphyritic gneiss, as respects the older strata, but differs by including the equivalents of the Coös group with the older series. Subsequently Dr. Hunt suggested the use of the adjective *Montalban* instead of White Mountain.

I have presented these statements for two reasons,—first, to correct a misapprehension of Dr. Hunt, stated in public on two occasions, in reference to the question who first assigned the White Mountain rocks to their proper place beneath the Cambrian; and, second, to justify myself, as the originator of the term White Mountain series, in restricting its application, and returning to an older name for the large division, first suggested in 1835.

In the *Proceedings of the American Association for the Advancement of Science*, vol. xxii, p. 116, after expressing the opinion that the White Mountain rocks are pre-Cambrian in age, Dr. Hunt says, "this view is, I believe, adopted by Prof. Hitchcock." A similar expression is made use of in the *Proceedings of the Boston Society of Natural History*, vol. xv, p. 310. It would appear, however, from the historical statements given above, that Dr. Hunt, rather than the author, has "adopted" this view. It is to be presumed that both of us arrived at the same conclusion independently of each other; while it is to the credit of the New Hampshire geologist that his official report contained the first announcement of the use of a term derived from the geography of his field of labor. That this new use of the name White Mountains should be employed by so able an investigator as Dr. Hunt, only two years after its suggestion in the state report, is confirmatory evidence of the appropriateness of the designation.

In 1812 and 1817, William Maclure published geological maps of the United States, on which is represented an area of "primitive rocks" extending from Maine to Alabama, and including the Adirondack region. From the accompanying text it appears that these rocks are regarded as a *formation*, and as the oldest known in the country.

In 1835, G. W. Featherstonhaugh, in a report upon the "Elevated Country between Missouri and Red Rivers," urged the necessity of giving a general name to the chain

of mountains, as well as to the formation holding them, occupying the region of the primitive rocks of Maclure. The mountains specified are the Blue Ridge, Alleghany mountain, Iron mountain, Unaka, etc., and the name proposed is that of *Atlantic Primary Chain.** From further remarks by Mr. Featherstonhaugh, 1836, in his report of a geological reconnoissance by way of "Green Bay and the Wisconsin Territory to Coteau de Prairie," it appears that he intended to have the name Atlantic applied to these primary rocks in the same sense that Cambrian and Silurian were applied to formations in England by Sedgwick and Murchison. He says, p. 38,—"the terms primary and primordial are, undoubtedly, always very properly applied to the lower rocks, to which an igneous origin has been attributed; but may fairly be extended to any series of rocks constituting a great geographical boundary, to which they give a predominating character, especially at a period when the term transition is passing into disuse, and leaves the term primary freed from theoretical views, to class all the rocks in below the secondary order." In his "secondary," he expressly includes the Cambrian of Sedgwick, so that his application of the term Atlantic is free from ambiguity. It includes the geographical area of crystalline rocks from Maine to Alabama, which are supposed to be pre-Cambrian. This proposition was objected to by Prof. W. B. Rogers, state geologist of Virginia, in his *Geological Reconnoissance*, published in 1836, on the ground of "superficial and precipitate generalization." It was at this time that Messrs. H. D. and W. B. Rogers, and other eminent geologists, began to entertain the notion that the New England portion of the Atlantic crystalline area consisted of metamorphic paleozoic strata. If this were a theory, confirmed by explorations, then the adoption of Featherstonhaugh's suggestion would have led the world astray. Inasmuch as the metamorphic theory blinded the eyes of geologists for thirty years, the proposed use of the word Atlantic was lost sight of; and those of us who now find that the older theories best explain the phenomena discovered by exploration had forgotten Featherstonhaugh's proposal, and had made use of the term White Mountain series in its place. But now, finding that the proposal proves to be correct, we cannot do better than accept it, to the exclusion of the term Montalban, for application to the entire system. Meanwhile, the necessity for the use of a geographical term for the oldest rocks led Sir W. E. Logan to apply the terms Laurentian and Huronian to the primitive formations in Canada, expressly to the exclusion of the Atlantic rocks, as this author believed, in the Paleozoic age of the New England crystalline schists; and these terms have been generally adopted. Featherstonhaugh did not know that the "primary" group was susceptible of subdivisions; but the study of the eastern belt of crystalline schists by Dr. Hunt led him, in his address at Indianapolis, to refer them to the White Mountain

* The original proposition is couched in the following language: "It will be apparent, I think, to every geologist, that as this primary chain is the true boundary of the sedimentary rocks lying west of it, and forms so important a feature in the mineral structure of the country, it should receive a clear geological designation; and as it looks upon the Atlantic coast in its whole course, I shall propose the name of the ATLANTIC PRIMARY CHAIN." *Featherstonhaugh's Report*, 1835, p. 33, *second edition*,—as the one printed with the reports of congress does not contain this paragraph.

series,* a group of rocks intermediate between the Laurentian and Cambrian, and exclusive of the Huronian. This proposal will relieve a multitude of difficulties, and enables us to place the Atlantic system midway between the most ancient Laurentian and the Paleozoic, so that both parties in the metamorphic controversy may be pleased because their opponents are not altogether in the right. Furthermore, the express exclusion of the New England rocks from the Laurentian, and the omission of all reference to the true Laurentian areas by Featherstonhaugh in his definition of Atlantic, enables us, both by a true regard for historical accuracy and correct geological discrimination, properly to apply the latter term to the eastern belt of crystalline strata, from New Brunswick, through New England, south-eastern New York, etc., east of the great valley of Virginia to Alabama.

There is a modification of the term Montalban now requiring specification. The White Mountains contain of this system only the tender friable gneisses described by Dr. Hunt, with the layers carrying andalusite and the Concord granite. Our researches show that the rocks of this geographical area properly constitute a separate division of the whole gneissic series of New Hampshire, and therefore Montalban may naturally be restricted to express these and no others. The present chapter indicates other modifications also. First, the porphyritic gneiss is older than any other of the gneisses, and may for the present be removed from the Atlantic system, partly because it may be represented in the true Laurentian, and partly because, in generalizations respecting the growth of the North American continent, the Atlantic border rocks seem to have had a later origin. Explorers in the Laurentian fields will do a great service by ascertaining whether the porphyritic rocks cannot be separated stratigraphically from the firm massive pyroxenic gneisses, which are so distinct from the tender schists of the east. The porphyritic gneiss has been included in the Atlantic and Montalban series by all writers in publications previous to the present. It is said to be a very conspicuous formation in North Carolina, where it is regarded by Prof. Kerr as the oldest of the crystalline series. Second, in New Hampshire the Bethlehem, Lake, and Franconia series seem to be independent formations, separable readily for stratigraphical reasons from each other, and from the Montalban. The second distinction was first drawn by us in 1873, at the Portland meeting of the Association for the Advancement of Science. See vol. xxii, p. 123. I am disposed now to group all these older strata as follows:

A. PORPHYRITIC GNEISS AND GRANITE, *perhaps* LAURENTIAN.

B. ATLANTIC SYSTEM.

1. *Bethlehem Group.*
2. *Lake Group.*
3. *Montalban Group.*
4. *Franconia Group.*

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* In what I have said concerning the priority of suggestion in respect to the White Mountain series, I desire it to be distinctly understood that to Dr. Hunt is due the credit of first assigning these rocks to a new system of different age from any described formation, though he has unfortunately included some later rocks with them. I

The Labrador Period.

Let us now consider the main topographical features of the area above water at the commencement of the Labrador Period. From some unknown spot in Maine, the country rises to the Mt. Washington range in New Hampshire. These peaks probably did not rise so high as at present above the water. The range continued southerly through New England, spreading out broadly about the Winnipiseogee region. Westward the fundamental ridge of the Green Mountains stretches its length along, passing southerly to form the New York and New Jersey highlands. Between the White and Green ranges lies the long, shallow island from Essex county, Vt., to Massachusetts, on the west side of the present Connecticut valley. The land on the two sides of the Connecticut nearly unites along the north Massachusetts line, while the ocean broadens and deepens northerly towards Canada.

In consequence of the strain exerted upon the infant continent by lateral pressure, there may have been a break in the strata along the upper Saco valley, say above Sawyer's river. The result would be the upthrow of the White Mountains from Mt. Webster to Mt. Madison, and the settling down of a considerable tract of land to the west of the Saco. There would result, therefore, a depression or hydrographic basin over a part of the White Mountain area, with these limits: bounded easterly by the Washington range, the Carter mountains and their foot-hills in Bean's Purchase, Jackson, and almost by the Maine line; southerly, by the foundation ridge of the Chocorua range between Conway and Black mountain in Sandwich; westerly, by the Moosilauke-Kinsman range; northerly, by the gneiss in Bethlehem and Cherry mountain in Carroll. Corresponding depressions, not necessarily produced by a sinking of the land, appear in Kilkenny, Stark, Columbia,

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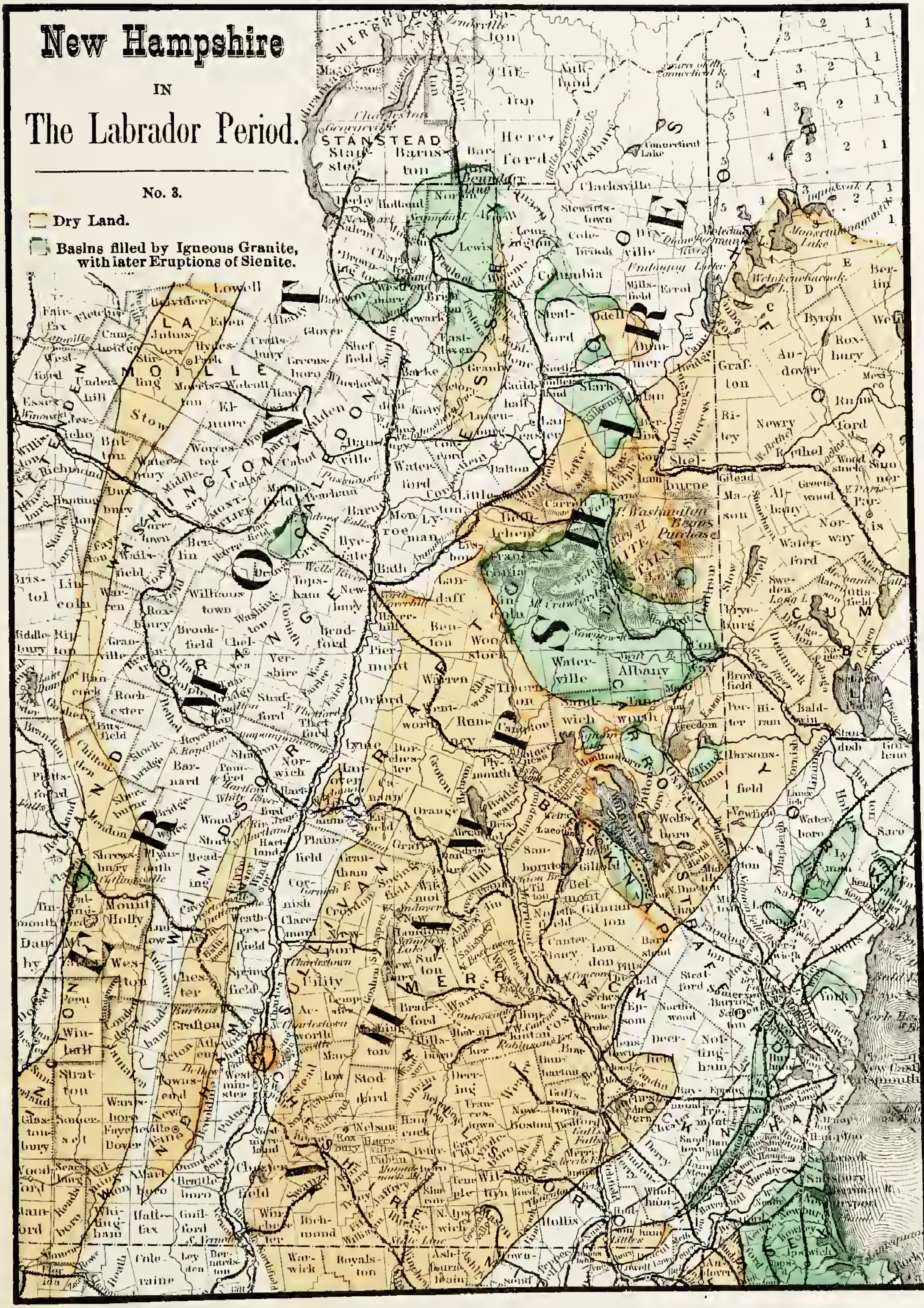
claimed the merit of having previously recognized the rocks as older than the Silurian, but had not in mind any definite place for them. I remember my father, in conversation, once expressed to me his conviction that the New England rocks would prove to belong to a system distinct from anything then known, and of about the age of the Cambrian; and I also recollect expressing emphatically a similar opinion at the Chicago meeting of the American Association for the Advancement of Science in 1868; but these surmises were not developed into reasonable theories by hard study. Neither of us could claim the credit of first describing this system in the full sense of the term, any more than my father could claim the invention of the telegraph; for, in a popular lecture upon galvanism, delivered at Newburyport, Mass., some years before Prof. Morse's discoveries, he declared his belief that, by means of galvanic electricity, people would ere long be able to communicate with each other instantaneously at stations many miles apart. These surmises were all creditable, but did not lead to the actual discoveries.

Essex county, Vt., and elsewhere, as shown upon the third of our map illustrations. The Pemigewasset basin was the largest of any of them. Such a terrible earthquake as must have accompanied the sinking of this land could not very well have passed away without leaving behind a copious outflow of igneous matter. Immediately subsequent to the cataclysm, we find indubitable evidence of the largest eruption ever known in New Hampshire. This Pemigewasset area was speedily overspread by a mass of liquid granite, oozing out from the rent in the gneiss, reaching down to the igneous reservoir. From the Crawford house to Mt. Lafayette, and from the White Mountain house to Mt. Whiteface, and from Franconia to Conway, the country was flooded. Were there ships of steel they might have floated on this liquid lake, for the surface was as level as the ocean.

Possibly the outlet of the fiery flood lay along the Saco valley in the line of disturbance. That this flood is not a myth, I would point to its localities, and claim that its surface is well marked to-day. Remove the overlying rock, and the top of the granite will appear as flat as a western prairie. The igneous material I call the *granite of Conway*, since the most of this town is underlaid by it. It appears also from the Flume to the Basin in Franconia, constituting much of Mts. Profile, Osceola, Fisher, and a host of peaks in the unexplored Pemigewasset area. The Notch has been excavated out of it, also the valleys of the Saco, Swift, and Mad rivers and their tributaries. It is not entire, as when formed, since the tooth of time has gnawed into it, or eaten through in a few instances. Very soon the uneasy earth vomited out another igneous flood, covering the same area, and nearly as great a quantity. Modern volcanoes are apt to throw out lava of slightly different mineral character at successive epochs of eruption. So it was with these ancient New Hampshire vents. The second overflow is a granite, spotted with rounded crystals of feldspar, and scarcely any quartz is present. The first carried a considerable quartz. The second verges into a compact feldspathic mass. I call it the *Albany granite*. If you desire to see localities, visit Welch mountain, Mts. Flume and Liberty in Franconia, the summit of Profile, the Twin mountains, and certain peaks in Bartlett and Jackson, besides many elevations in Albany. This material thins out in the east. Beneath Pequawket it is not over one hundred feet thick, while it is eight


New Hampshire
IN
The Labrador Period.
No. 3.
Dry Land.
Basins filled by Igneous Granite, with later Eruptions of Sienite.

hundred or one thousand feet elsewhere, as in the Twins, and Mts. Flume and Liberty. It crops out also near the summit of Lafayette. A third outburst was more limited, but it gave rise to the sharp peak of Chocorua and to small hills west of Mt. Hancock, which I term the *Chocorua granite.* It is likely that corresponding eruptions gave rise to similar granites in the Starr King group of mountains, Stratford and Columbia, the granitic country of Essex county, the gores of wild land east of Montpelier, Little Ascutney, and about Cuttingsville, Vt., besides the Ossipee mountains east of Winnipiseogee. Possibly the latter may have accumulated by a branch stream running southerly from the Saco river outburst. This granite, when finally cooled off, seems to have been covered by water, since there succeeds a great thickness of fine sedimentary deposits. This proves to be of four kinds,—coarse and fine labradorites and variously colored potash feldspars above the first. We suppose these must have covered the granites, or nearly so. When this basin was full, there would be a level country from Lafayette across to Mt. Tom, just back of the Crawford house.

It seems strange that the topographical aspect of a portion of the White Mountains more nearly resembles the eroded Carboniferous plateau of West Virginia than any other district. The character of these mountains may be predicted in advance of examination, since there is so general a correspondence between altitude and lithological structure. If a five-thousand-feet mountain shows the Conway granite at its base, felsites may be looked for at its summit. Pemigewasset has in it three mountain ranges running southerly,—Lafayette on the west, and Mt. Tom on the east; both these and the central Twin mountains show the whole series from the low granite to the upper felsites, while the intervening ranges have been removed by erosion down to the lowest granite, the formations reposing horizontally. This is like the narrow valleys in West Virginia, cut through by the Kanawha and Guyandotte rivers and their tributaries. The map shows a smaller Labrador area resting upon the Green Mountain range near Cuttingsville on the Rutland & Burlington Railroad, and not a great distance from Rutland. This area is composed apparently of the Chocorua granite, resting upon Montalban gneiss. It is an interesting locality, because it shows the similarity between the formation of the White and Green mountains. The succession of the

granites and felsites in the former is satisfactorily worked out. The Chocorua rock is essentially a crystalline labradorite. Now this is a mineral usually regarded as very ancient. Whatever it overlies must therefore be older. Hence the Montalban rocks are more ancient than the Chocorua granite in New Hampshire; and, as we find the same formations near Rutland, and grouped in the same way, it is fair to infer that they belong to the same series as those in New Hampshire. Therefore we have a new argument for the Eozoic age of the Green Mountain range. I wait only for the results of certain chemical analyses to publish the details of this discovery, and its bearing upon the age of the Vermont formations.

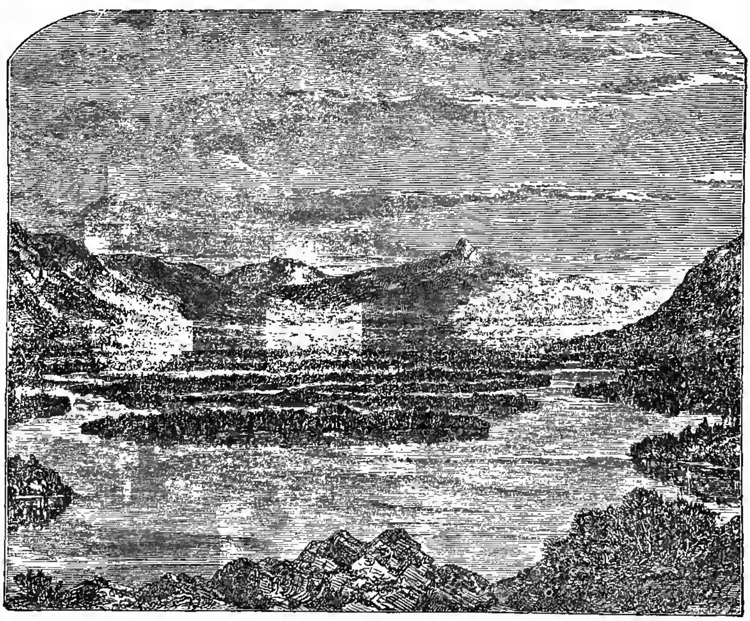


Fig. 61.—SQUAM LAKE AND MT. CHOCORUA.

Several of the Labrador areas upon the map represent an important eruption of sienite after the deposition of all the members which have now been specified. Such are the elliptical area in Moultonborough and Sandwich, or Red hill; part of the Waterville patch, consisting of Mt. Tripyramid; the long strip from Dover to Salem; the northern end of the large expanse of this rock in Massachusetts; Mt. Monadnock, opposite Colebrook, etc. Up Norway brook in Waterville this rock has

very plainly oozed through crevices in the ossipyte. Evidence of intrusion at this period is not yet obtained from any other locality; but, as the lithological character of all the previously erupted members is constant, it is probable that these sienites were all produced simultaneously, most likely at the close of the Labrador period. Thus this age of the world in New Hampshire possessed a fiery character. It was ushered into being by an overflow of igneous material, nourished with ejections of molten rock, and terminated by upheavals, rending of the strata, and pouring of fiery sienite into the crevices, which oozed out and formed mountains.

The Labrador formation was separated formally from the Laurentian by Sir W. E. Logan, in 1865. It is developed quite differently in Canada from its usual aspect in the White Mountains. Logan estimates the thickness of the anorthosite gneisses of this system at thirteen thousand feet. They are inter-stratified with orthoclase gneiss, quartz, and limestones. I do not find, from the descriptions, that there is any great difference in the angle of the dip between the Labrador and Laurentian.

But there is a closer resemblance between the New Hampshire and the Canadian Labrador rocks, on the north shore of the St. Lawrence beyond the Saguenay river, according to James Richardson. He says the Laurentian gneiss is nearly vertical, with a north-south strike, and much broken, while the Labrador rocks dip at comparatively moderate angles, strike nearly east and west, and are free from contortions and disturbances.* In the Adirondacks, the descriptions of Prof. Emmons would indicate that the labradorite rocks occupy the centre and highest part of the Eozoic area, and, on this account, they bear some resemblance to the Pemigewasset exposures.

I think geologists will find my descriptions of the New Hampshire Labrador rocks different from anything that has ever been published. I cannot find any author pointing out areas whose molten granites have been spread out like lava over a considerable tract of country, nor a definite succession of granitic overflows characterized by different mineral composition. The brief itinerary of Mr. Richardson affords a hope that the bleak, northern shores of the lower St. Lawrence will confirm our views of the structure of the Labrador formation, when they have been

* *Geol. Survey of Canada. Report of Progress.* 1866–1869, p. 305.

carefully explored. Meanwhile I would bespeak the attention of my brethren of the hammer to the brief statement of my theory in this chapter, to be followed by fuller technical descriptions in the next volume. If confirmed by further research, these studies will throw much light upon the origin of granite, and may indicate the existence of the Labrador system in many localities where nothing of the kind is now suspected.

The Huronian Age.

As far back as 1822 my father distinguished this formation in Massachusetts from all the other crystalline schists by the names of talcose and chlorite slate.* Essentially the same delineation has since appeared on all the geological maps of Massachusetts. The Vermont geological map shows its continuation through that state. In 1857, Prof. H. D. Rogers proposed to distinguish this formation farther south, in Pennsylvania and Maryland, by the name of *Azoic*, separating it from the underlying *Hypozoic* gneisses. He regarded the group as older than his "Primal series." In 1858,† I understood him to express his belief in the equivalency of the Azoic with the formation called Azoic system by Foster and Whitney in Michigan (1850), as separated from their "igneous granite," and with the Huronian system of Logan, described in 1855. Singularly enough, while Prof. Rogers perceived the true position of the Pennsylvania rocks, he believed the New England talcose series to be metamorphic Paleozoic. James Macfarlane seems to have been the first to express the opinion that the Canadian and New England area was of Huronian age. In this opinion he was speedily followed by Prof. Hermann Credner in 1869, and by Dr. T. Sterry Hunt in 1871. In my first annual report I accepted Logan's interpretation of these rocks, calling them altered Quebec, and belonging to the Lower Silurian, but since 1871 have thought it better to refer them to the Huronian.

The Huronian rocks, as seen by the fourth of our maps, have not played a very important part in our history, judging from the small areas now occupied by them. But the amount of time occupied in their deposition, alteration, and elevation much exceeded the length of the previous eon.

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* *Amer. Jour. Sci.*, I vol. vi, p. 26. † See *Proc. Boston Soc. Nat. Hist.*, vol. xv, p. 306, for further references.


NEW HAMPSHIRE
AT THE CLOSE OF THE
HURONIAN PERIOD
No. 4.
Dry Land.
Additions during the Huronian Period.

We find peculiarities in the arrangement of land and water in this age not before exhibited. All the porphyritic and Atlantic rocks have become solid terra firma, possibly covered by a scanty cryptogamous vegetation, sufficiently green to redeem the state from sterility. This land is mostly along a central line in the state, passing transversely through New Hampshire to Massachusetts, with an ocean upon each side. That upon the south-east has left no visible traces of its existence in our state, but deposited much sediment over Casco bay in Maine. The land probably extended beyond the Isles of Shoals, so that the deposits of this age are now concealed by water. On the west and north-west side the ocean extended up the Connecticut valley to Groveton, and thence, by way of the upper Ammonoosuc branch, to Umbagog lake, possibly connecting around the north side of the Stratford-Odell Labrador granites with a broad expanse northerly, much wider than below and practically without limit, towards the Gulf of St. Lawrence. It is uncertain whether the Connecticut valley ocean connected with the greater body of water washing the east flank of the Green Mountains. The Montalban ridge, between Waterford and Reading, Vt., may have been of sufficient elevation to separate them. If so, the next point of connection on the south was in Connecticut.

The deposits formed in this period indicate quietness in the waters. They are not now visible south of Bellows Falls in the eastern arm, and are not certainly connected between Berlin and Columbia. They are two or three thousand feet in thickness.

A marked feature in this ocean appears in its metalliferous character, since pure gold, and the sulphurets of iron, copper, and lead, separated themselves from it. Gold is soluble slightly in ferric solutions; and hence we may infer the presence of per-salts of iron in the water, which leached out from the sandy bottom infinitesimal particles of gold existing as impurities. It was a process of concentration, and agrees with our inspection of the rocks now,—for the talcose rocks carry more gold than the gneissic,—and subsequently it accumulated still more abundantly. Supposing that ferric sulphates containing gold in solution abound in the Huronian ocean, it is easy to understand how the metal should be precipitated in the pure state. Some deoxidizing agent acts upon the ferric sulphate, and reduces it to the ferrous condition, and at the same time

the sulphate is reduced to a sulphuret. Gold is not known in nature as a sulphuret, though commonly diffused through pyrites; hence it is presumed that the precious metal was precipitated simultaneously with the deoxidation of the sulphates, not passing through the intermediate condition of a sulphuret. The deoxidizing agent was probably vegetation.

The accumulation of the large beds of iron and copper pyrites in Gardner's mountain was brought about at the same time, and under similar conditions. For the formation of sulphurets we require originally a sulphate ocean, just as in the case of gold. The deoxidizing action of vegetation will reduce the sulphates to sulphurets; and thus deposits of pyrites of enormous extent may be produced, provided there is a sufficient store of the iron and sulphur. In natural waters, containing sulphates of lime and magnesia, the process of sulphate reduction in the presence of decaying plants may be observed at the present day; and, if carbonic acid be present, sulphuretted hydrogen gas is also evolved. The same principle is made use of in analytical laboratories for the separation of metallic sulphurets. A stream of sulphuretted hydrogen is passed into metallic solutions, when the element readily combines with the sulphur, producing an insoluble sulphuret, which is precipitated. The copper pyrites is so closely connected with the iron that it has probably been accumulated in the same way. In the Ammonoosuc gold region copper is very common as an impurity in the strata at localities remote from valuable beds of ore; so that the sulphate ocean must have been highly charged with the mineral solutions. The formation of the lead sulphuret may be described in similar terms.

By referring to an argument set forth above for the existence of vegetation, it will appear that the formation of the iron oxides is akin to that of the sulphurets. Vegetation is the agent required at the present day for the production of both; hence, by looking at the process in another way, we may derive a different conclusion. The ores of iron and copper require, at the present day, the presence of vegetable matter for their formation. These ores accumulated largely in the Huronian age; hence it is probable that plants existed at this time. No other evidences of their existence have yet been discovered.

There are three divisions of this age:—First, the period of the deposition of the copper and iron beds, with an auriferous tinge. Second, the

formation of a very fine siliceous mud, with dolomite, soapstone, and serpentine. More gold was deposited in this period than in the first. Third, the formation of a small bed of conglomerate composed of quartz pebbles, possibly derived from the rocks of the first and second divisions. Some gold is present in this conglomerate, which seems to be mechanically mixed with the pebbles. This bed indicates the existence of a strong current, sufficient to carry along fragments of gold.

The relations of the Huronian to the Labrador series are interesting. Fig. 61 shows a section from Northumberland falls to Pilot mountain. Between Mts. Lyon and Pilot the middle member of the Huronian is disposed in synclinal form, and reappears on the west. The junction between the quartzite and felsite is obscured by drift. Near by an exposure has been discovered where the quartzite stands vertically, abutting against the felsite. On breaking off large masses of the quartzite, the felsite was seen extending downwards, whence it appears evident that the felsite was the oldest, underlying the slate unconformably. It is therefore probable that the felsite of Mt. Pilot unites with the rock of Mt. Lyon underneath the Huronian.

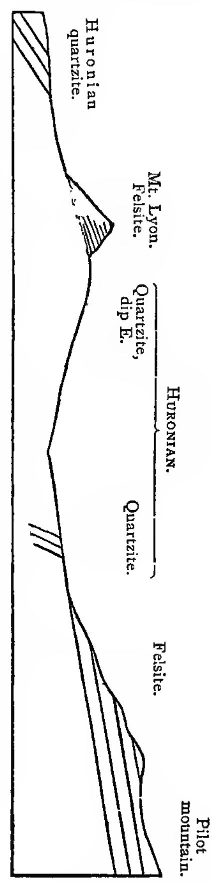


Fig. 62.—SECTION FROM NORTHUMBERLAND FALLS TO PILOT MOUNTAIN.

When the crust of the earth was shrinking, I suppose that the felsite hills were brought nearer together without essentially disturbing their stratification. The rock is massive and very tough; while the slaty Huronian rocks between them were pliable and easily doubled up by the lateral shoving force. This conjecture will explain the seeming anomaly of horizontal rocks being older than the adjacent highly inclined strata.

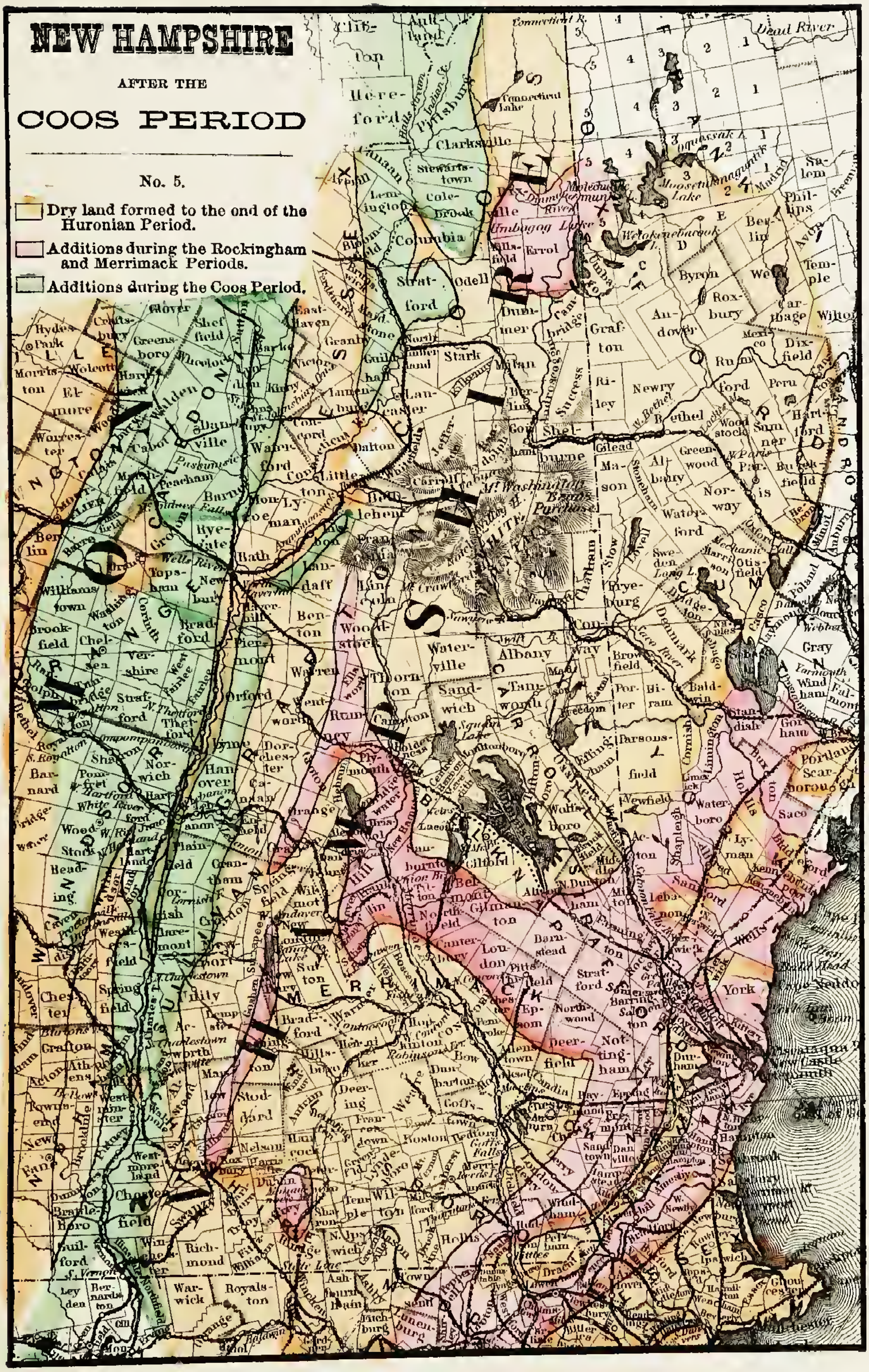
The Huronian strata are remarkable for dipping at a very high angle, almost constantly. The commencement of their inclination was probably induced at the close of this period, since these strata are much more highly inclined than those deposited in the following age.

THE MICA SCHIST PERIODS.

The fifth of our map illustrations represents by one color all the formations that have been deposited in New Hampshire to the close of the Huronian; the other shows the positions of the areas occupied by several groups which were evidently deposited subsequently, and may belong to one great system. They are thus placed, however, provisionally. They are the Rockingham mica schist, the Merrimack group, Cambrian, auriferous clay slates, and the Coös group.

The Rockingham schist occupies the principal portions of Rockingham, Strafford, and Belknap, with a part of Merrimack and Hillsborough counties. Over this area it is generally an uncouth mica schist. West of the Merrimack river there are several long, narrow areas of mica schist supposed to belong to the same group. A broader range, extending north-easterly from Deering through Henniker and Hopkinton, is highly ferruginous. A similar band occupies most of Weare and Francestown. A cleaner mica schist makes up the substance of the mountain range extending from New Ipswich through Sharon, Temple, and Lyndeborough. All these areas cover Atlantic gneisses unconformably. They lie upon them like a blanket, and hinder us much in our attempts to study the older formations. The Merrimack group is a micaceous quartzite lying adjacent to the Exeter sienite range on the north-west, and has not yet been separated from the previous group. The occurrence in it of large beds of soapstone, as at Groton, Mass., is suggestive of the Huronian age. It abounds in beds of coarse indigenous granite, which seem to have been altered *in situ* from feldspathic conglomerates. In certain parts of Strafford county these granite beds predominate, forming numerous hills, while the slate occupies the valleys between.

The schists south-east of the Exeter sienite range may belong to the same Merrimack era; but they are traversed by several narrow bands of clay slate. Possessing a north-west strike, these slates are thought to be the equivalents of the Paradoxides beds of Massachusetts. It is obvious that the physical aspect of the country must have been very different from what it was in the Merrimack period. The Merrimack schists must have been elevated, then they were cut across by streams flowing south-


NEW HAMPSHIRE
AFTER THE
COOS PERIOD
No. 5.
Dry land formed to the end of the Huronian Period.
Additions during the Rockingham and Merrimack Periods.
Additions during the Coos Period.

easterly. Afterwards the land sank, and these chasms were filled up with mud, which eventually became converted into Cambrian slates.

Not far from the same epoch long bands of clay slate were deposited in the Connecticut valley, extending from the Massachusetts line to Coös county. In some parts of this formation large veins of auriferous quartz were formed, whose metallic contents were derived from the Huronian strata, and more effectually concentrated than before. Many of the veins afford evidence of having been deposited from hot water. The layers of accretion are easily distinguishable. The gold may have been reduced from solution by the same process as that recently described. These auriferous deposits are of sufficient richness to be worked to advantage.

The Coös ocean occupied very much the same position as the Huronian. Along the Connecticut valley it covered the greater part of eastern Vermont, in Orleans, Essex, Caledonia, and Orange counties.

The Waterford-Reading ridge did not separate the waters of the Connecticut valley from those just mentioned farther west. The Vermont part of the deposit is mostly calcareous. A few scanty remains of crinoidal stems have been taken from this rock in Derby, Vt., showing that life existed. Bordering Connecticut river in New Hampshire, from Haverhill to Hinsdale, the Coös rocks are composed chiefly of quartzite, mica schist, and slates full of crystals of staurolite and garnet. This deposit therefore consisted originally of clays of various composition. Overlying the Atlantic gneisses, between Landaff and Keene, is an extensive deposit of andalusite mica schist, including Mts. Carr and Moosilauke. Mt. Monadnock is an isolated mass of the same rock, as is also the Kearsarge-Ragged area. These schists have but recently been distinguished from the adjacent rocks, and may be the equivalents of the Coös group. If formed at the same time, the depositing ocean may have been separated from the Connecticut valley by an Atlantic ridge. The strata correspond in thickness very well with that of the staurolite rocks.

The Connecticut Coös period can easily be divided into three parts,—first, the epoch of the deposition of mountain masses of silica; second, of hornblende and mica schists; third, of limestone.

The enormous veins of copper and iron pyrites in Strafford and

Vershire, Vt., and those described in Hanover, Lebanon, etc., prove that a more concentrated sulphate ocean existed in this than in the Huronian period.

In the White Mountain region there are several small areas of andalusite slate, supposed to be the equivalent of the Coös group. They occur upon the east side of Mt. Washington, Mts. Willard and Tom, Mt. Pequawket, and farther south in Farmington and Rochester. These facts seem to indicate that the White Mountains were considerably depressed during the Coös period, probably more so than the Green Mountains, since no slaty beds of this age have been found resting upon the Montalban or Huronian areas of Vermont.

The Coös period was terminated by eruptions of sienitic granite. The conical Mt. Ascutney is the best example of this igneous material. Others are Black mountain, Dummerston, the Washington and Essex county mountains, Vt., Iron-ore hill, near Haverhill, and the singular concretionary granite of Craftsbury, Vt. The Coös quartzite now constitutes a distinct range of mountains.

At some unknown epoch, posterior to the consolidation of the andalusite slates, there was a considerable eruption of igneous material, producing Mts. Mote and Pequawket. The paste, cementing together the slaty fragments, bears some resemblance to the Albany granite, except in the abundance of dark spots commonly present. I think the rock on the top of Mt. Willard will probably turn out to belong to the Mt. Mote series.

The Helderberg Period.

For a very long period of time New Hampshire furnishes no indication of geological changes. Our next formation was deposited at the very close of the Silurian era. Fossils have been found which identify the strata with those of the Helderberg mountains in New York.

The ocean must have retired from the Connecticut valley after the deposition of the Coös rocks,—otherwise there would have been formed ledges to indicate the fact of continued submergence. The Helderberg ocean probably covered the same area with the one just described west of the Atlantic ridge, bordering the quartzite. The Helderberg rocks occupy isolated areas in Bernardston, Mass., Hanover, Lyman, Lisbon,


NEW HAMPSHIRE
IN THE
HELDERBERG AGE.
No. 6.
Area supposed to have been submerged.
Dry Land.

Littleton, etc. Most of these patches contain crinoidal and coralline limestones. It is hence inferred that the Connecticut valley was deeply covered by the ocean, as polyps and crinoids do not flourish in limited expanses of salt water. In New Hampshire crinoids, gasteropods, brachiopods, corals, and fucoids are known to have flourished. The ocean probably supported in addition echinoderms, trilobites, large crustacea, and ganoid fish. The land may have been covered with the higher cryptogams and coniferæ. Numerous hills, covered with vegetation, gave an unusual variety to the landscape.

It is difficult to note precisely the limits of the Helderberg ocean. There is reason to believe that northern New England and Canada sank deeper than at any previous period, or at any time since. Outcrops of the Helderberg rock abound in Quebec and northern Maine. The locality at Lake Memphremagog may have been connected with the New Hampshire ocean north of Essex county, as the highest of these rocks in our state are elevated nearly one thousand feet above the level of the sea. I have drawn the south-eastern shore line to correspond with the second of our contour lines. The map also indicates that no evidence exists of a submergence in this period in the south-eastern part of the state.

The age may be divided into three periods,—first, the epoch of the deposition of sandstone; second, of coralline limestone; third, of great thicknesses of slate, schist, and conglomerate. The latter rock is composed chiefly of pebbles derived from the Huronian and Atlantic rocks, with a few of the Coös limestones.

The Glacial Period.

During the whole of the Devonian, Carboniferous, Permian, Mesozoic, and Tertiary periods, New Hampshire stood above the level of the sea, and may have included a considerable area beyond the Isles of Shoals. No record has been left of any event that transpired within our limits during this immense lapse of time. The land was probably covered with vegetation, and animals roamed over the hillsides, judging from the conditions known to have existed in the adjacent territory. In Vermont, during the early Tertiary, there were certainly forests of hickory, beech,

cinnamon, and coniferous trees, with a warm temperate climate. The same must have abounded in New Hampshire.

At the close of the Tertiary period, ice began to accumulate, and there was ushered in an immensely long period when the state was covered with glaciers, and the climate corresponded with the present state of things in Greenland. I have no time to enter fully into the history of this period. In general, four periods are represented,—first, when the state was entirely covered with glacial ice thousands of feet in thickness and moving in a southerly direction; second, when local glaciers were prevalent; third, the Champlain or terrace; fourth, the historic period. Our map is designed to illustrate the movements of the ice during the first of these periods.

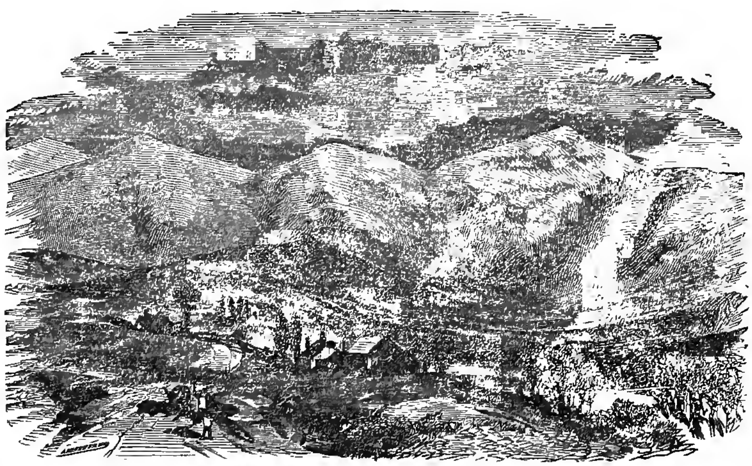


Fig. 63.—WHITE MOUNTAIN RANGE, FROM JEFFERSON HILL.

Four special features of ice-motion are suggested by studying the scorings upon the ledges:—First, the greatest amount of work seems to have been accomplished by the south-easterly direction of the sliding. This course prevails over the whole of Coös county, the White Mountains, and the higher peaks along the Connecticut-Merrimack water-sheds. The highest markings preserved stand at 5200 feet above the sea; but transported pebbles have been picked up 600 feet higher, on the north slope of Mt. Washington. This summit seems to be the only part of the state that has not been subjected to glacial action.

The ice in this period pursued a south-easterly course, with a reckless disregard of all obstacles. Mountains were scaled by the resistless mass, as is proved by the ice grooves running from base to summit, while the south-easterly slopes show scarcely any marks of scarification.

Second, nearly all the ice south of the White Mountains and east of the Connecticut basin pursued a southerly course. Mts. Monadnock, Kearsarge, and Ragged stood up as islands in this ice sea.

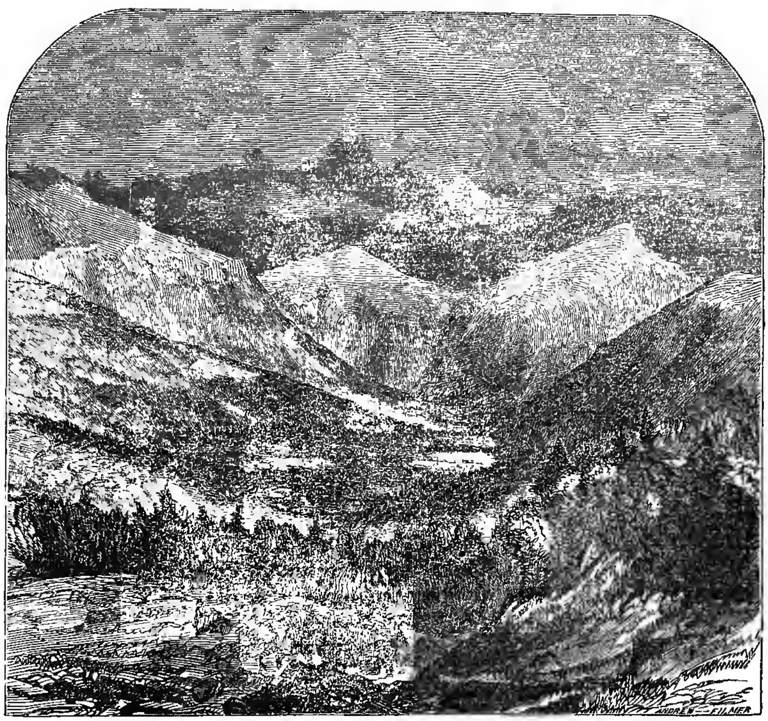


Fig. 64—MT. WASHINGTON, FROM THE GLEN.

[This illustration should be compared with Fig. 63, which shows the back side of the same mountains, as seen from Jefferson hill. In the first instance, the more gentle slope on the north side shows the smoothing, rounding action of the south-easterly moving ice; while, in the second, precipitous sides illustrate the fact of no erosion by the great continental glacier. As the force moved south-easterly, the ice would not act upon the south-eastern or lee sides of the mountains.]

Third, in the Connecticut valley south of Columbia, both in New Hampshire and Vermont, the ice moved a few degrees west of south, corresponding with the general course of the valley.

Fourth, a similar current passed down the valley of Baker's river to

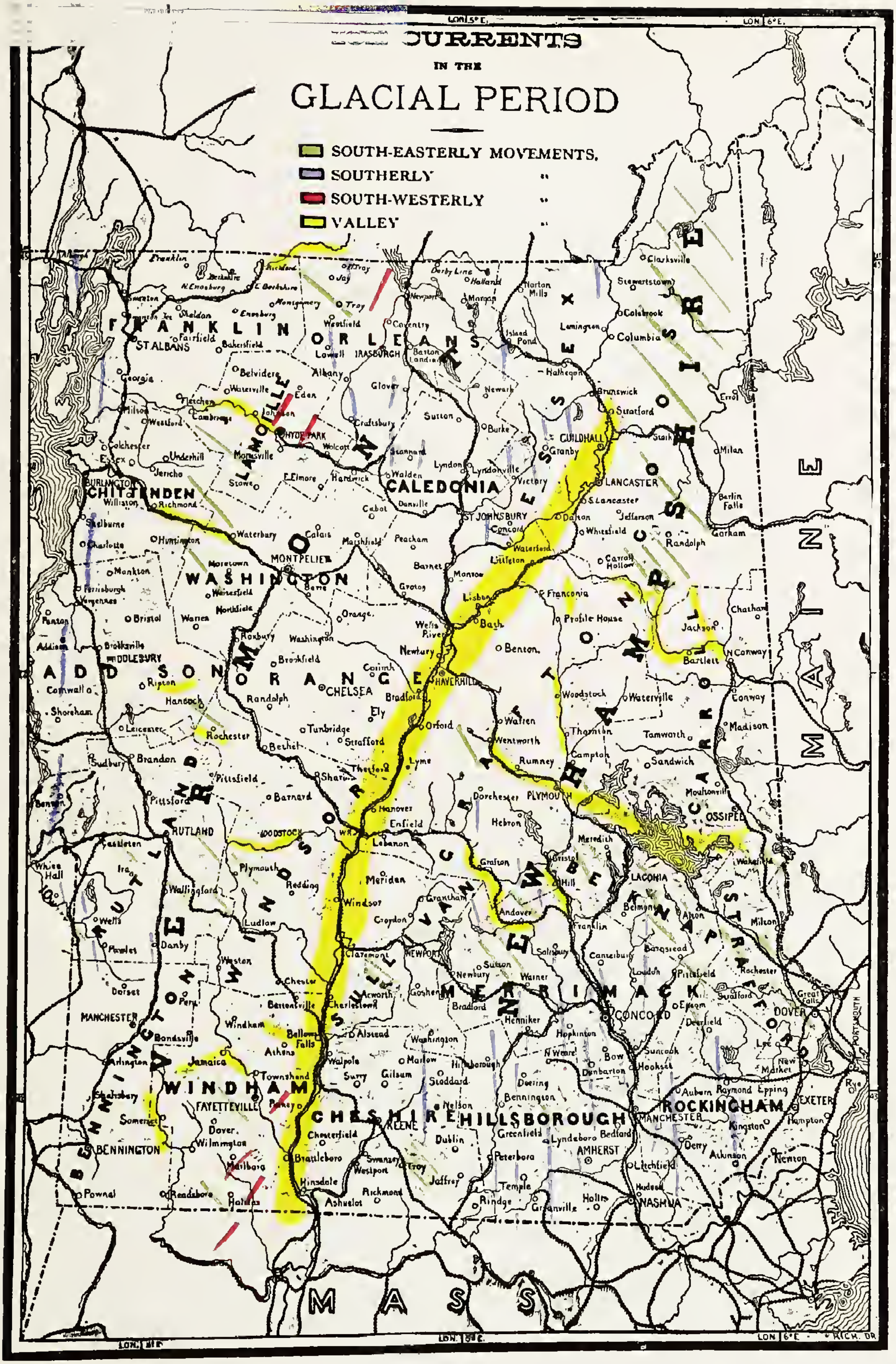
Plymouth, thence easterly to Squam lake, thence south 25° east over the Winnipiseogee basin, thence easterly around the south end of Ossipee mountain into Maine. Its course through Warren was southerly, and it curved to the east in Rumney before reaching Plymouth. The variation in direction corresponds with the course of an extensive valley.

A somewhat similar set of striæ follows the Northern Railroad from Grafton to Andover, passing down the valley of the Blackwater river between Mts. Kearsarge and Ragged.

A very few local glaciers have been observed about the White Mountains. Somewhat similar action,—pushing gravel away from the bases of large hills,—may be observed in every part of the state.

The terraces along the Connecticut and Merrimack rivers give us information of the next marked feature in post-tertiary history. Careful explorations along both these rivers show that the higher terraces on both sides slope from the sources to the mouths, corresponding very nearly with the fall of the stream. On the Merrimack the terraces in Ashland and New Hampton are fully 800 feet above the ocean; at Franklin, 470; at Concord, 450; at Manchester, 250; and very much lower in Massachusetts. Similar phenomena, though not so marked within our limits, may be seen on the Connecticut. We conclude that at the close of the glacial period, when the ice was melting rapidly, the rivers filled their valleys even with the tops of the highest terraces. The terraces are lower and broader nearer the ocean, but would require the same amount of water to cover them. When the flow of water had diminished, another set of terraces was formed, lower than and between the first. In a similar way the terraces still lower were produced.

During the terrace period the land was submerged certainly about two hundred feet and more, if reliance is placed upon the argument from maritime plants developed in a following chapter. Evidence of this state of things is afforded by the discovery of marine shells and whales' vertebræ in the coast region. The boreal character of the shells indicates a climate like that of the present Gulf of St. Lawrence. During this period the woolly elephant, wild boar, and primeval horse lived in the wilderness in company with the aborigines, whose implements of stone are so often plowed up in our fields. These wild animals have become entirely extinct, and the savages have migrated.


CURRENTS
IN THE
GLACIAL PERIOD
SOUTH-EASTERLY MOVEMENTS.
SOUTHERLY "
SOUTH-WESTERLY "
VALLEY "
FRANKLIN
ORLEANS
ESSEX
LAMOILLE
CALEDONIA
CHITTENDEN
WASHINGTON
ADDISON
ORANGE
RUTLAND
WINDSOR
BENNINGTON
WINDHAM
SULLIVAN
CHESHIRE
HILLSBOROUGH
MERRIMACK
ROCKINGHAM
STRAFFORD
CARROLL
BELKNAP
GRAFTON
COOS
NEW HAMPSHIRE
MAINE
MASS

Subsequently to the cold term indicated by the boreal marine shells, there are two classes of facts serving to indicate since that time, and probably within the human period, a long era when the climate over New Hampshire was milder than it is now. The evidences derived from our limits are the scanty remains of southern plants procured in a very few localities. They may be well represented by the *Rhododendron maximum*, mentioned in the catalogue of plants as occurring in Richmond, Fitzwilliam, and Grantham. Since the printing of that chapter, I have got traces of it in Hopkinton and Hooksett. The proper home of this shrub is in the Middle states. Its occurrence in insulated swamps suggests a former abundance in intermediate localities, and the presumption of a climate more like that of Pennsylvania, to enable it to flourish within our borders.

The other class of facts is represented by the discovery of several kinds of marine animals that properly flourish south of Cape Cod, on the coast of Maine, and the British provinces. The nearest locality is at Quahog bay, about thirty miles beyond Portland. More than twenty species of marine animals, according to Prof. Verrill, live in this bay, the most common of which is the quahog or round clam, whose proper habitat lies to the south of Massachusetts bay. Scarcely any of them are known to occur off the New Hampshire coast. In their stead are the more northern species, such as are at home in the waters of the Canadian district. This assemblage of extra-limital species is called a "colony," and, in order to understand why they live in such a place, isolated from their kindred, we may use the same theory which has just been applied to the occurrence of the *Rhododendron*. The climate formerly allowed the Alleghanian animals, as well as plants, to abound where now the colder Canadian species find the conditions of life congenial, and suitable for productiveness.

Another of these southern forms is the oyster. This occurs, living naturally, in the Sheepscot and Harriseeket rivers in Maine. It is supposed that both these edible mollusks once flourished along the whole coast. Further evidence is afforded by the discovery of numerous heaps of their shells in the piles of rubbish left by the aborigines, who used the animals for food. These heaps occur very commonly along the whole New England coast; and they seem to indicate that this milder

climate belonged to the early part of the human period, else the kitchen rubbish has no significance.

A similar colony is said to exist in the Gulf of St. Lawrence. Their continued existence in the Gulf and Casco bay may be explained in the same way. Both these bodies of water are comparatively shallow. This fact prevents the flow into them of the cold arctic current from the north, and allows the heat of the sun in the summer to moderate the temperature very considerably. The tides are not very powerful in these bays,—certainly not like the enormous ebb and flow in the Bay of Fundy, where the southern animals do not exist. The moderate tide prevents the thorough mingling of the cold and warm waters, and this is favorable to the continuance of the colonies.

The changes in the temperature of the bays seem therefore to be local in character, and to be readily accounted for by variations in the relative level of land and water. The deepening of the bays and the influx of the arctic current might kill off the more delicate animals, and thus exterminate the colonies; or, with the development of other contiguous shallow areas, the inhabitants may migrate to more salubrious climes. Could we become better acquainted with the present distribution of live animals on the land and beneath the water off the coast of New Hampshire, still other chapters might be added to our history.

I have now given a brief outline of the physical history of New Hampshire. Commencing with mere points of dry land, we have seen how the territory has increased in size from age to age, and have appreciated the fact that the state is quite ancient,—almost the oldest land in America. For much of geological time the record has been meagre. Entire races have peopled its surface, and left behind no evidence of their existence. No doubt the wonderful birds, which left their footmarks along the Connecticut valley in Massachusetts, built their nests among the jungles of New Hampshire, from whence they often emerged in search of food. And in the Carboniferous period immense forests must have covered our hillsides, even more luxuriant than the original growth which furnished so many magnificent masts for the royal navy of England. The last is the greatest of all the periods in our history. Man, the crowning master-piece of creation, has been introduced. The silence of the forests is broken with the axe; the savage beasts and aboriginal men, their com-

rades, melt away before the palefaces; railroads wind among the hills, climbing even to the top of Mt. Washington; and the state is inhabited by the most vigorous of the Anglo-Saxon race. Those who have been trained in our schools have gone forth to lead in the councils of state, and to be foremost in maintaining right and justice. The last is the best of all the periods. May its record grow brighter and more glorious to the end of time!

Fig. 65.—TRAVELLING ON SNOW-SHOES.

CHAPTER XVI.

THE RELATIONS OF GEOLOGY TO AGRICULTURE.

IN presenting briefly the relations of geology to agriculture, as especially applied to New Hampshire, it seems proper first to state a few fundamental facts, and then present the details that more immediately concern us.

The first inquiry in agricultural geology is, What is the composition of good soils?

The matter in all soils capable of sustaining vegetation exists in two forms,—inorganic, and organic. The first contains twelve chemical elements, viz., oxygen, sulphur, phosphorus, carbon, silicon, and the metals potassium, sodium, calcium, aluminum, magnesium, iron, and manganese. In the organic part the elements are four,—oxygen, hydrogen, carbon, and nitrogen. The inorganic elements are derived from the rocks; the organic elements from decaying animal and vegetable matter,—so that it is of the earthy constituents we must speak. They do not indeed occur in their simple state, but as water, sulphates, phosphates, carbonic acid, silicates of potassa, soda, lime, magnesia, alumina, iron, etc. The average amount of silicates or sand in soil is eighty in one hundred parts.

The second inquiry is, whether these elements of the soil are found in the rocks. By consulting the details of their analyses, as given in geological treatises, it will be seen that they are all present except phosphorus, which, however, is not unfrequently found in them in the condition of phosphates. Moreover, the proportion of the ingredients in the

rocks does not differ much from that of the soils. Hence the conclusion is that the latter are only the former comminuted, with the addition of from three to ten per cent. of organic matter.

Since the rocks differ considerably in composition, we should expect a corresponding difference in the soils derived from them. And such is the fact to a considerable extent, where the soil is simply the result of the disintegration of the rock beneath it. It is enough so in many districts to form characteristic soils. Thus, over quartz rocks and some sandstones we find a very sandy and barren soil, though it is said that in nearly all soils enough silicates of lime and magnesia are present to answer the purposes of vegetation; but the alkalies and phosphates may be absent. When the rock is limestone, the soil is sometimes quite barren for the want of other ingredients, and also in consequence of the difficulty of decomposition. Clay, also, may form a soil too tenacious and cold. The sandstones that contain marly beds, and some of the tertiary rocks of analogous character, form excellent soils. So does clay slate, and especially calciferous mica schist. The amount of potash and soda in gneiss and granite often makes a rich soil from these rocks, and the trap rocks form a fertile though scanty soil.

But, in the third place, in most countries, aqueous and glacial agencies have so mixed the soils together that their original peculiarities are lost, and new and compound characters are given them. This is particularly the case in northern countries, where the drift agency has swept over the surface, and torn off and mixed together the disintegrated portions of the several formations. Subsequently rains and streams have carried the finer portions of the drift into the lowest places, and there formed alluvial meadows, and, although these are usually the best of soils, they are often derived from many different rocks. The drift left upon the higher grounds is generally quite barren, chiefly because of its coarseness.

A fourth service which the geologist renders to agriculture is by the discovery of fertilizers. Sometimes he can point out deposits of the phosphates, either in a crystalline state, or as coprolites or guano. He can also show what rocks contain carbonate of lime, or discover sulphate of lime, or marl beds, or greensand, or decomposing fossil shells, or deposits of carbonaceous matter. He can also find what rocks contain enough of potash or soda to be of service when pulverized.

The Soils of New Hampshire.

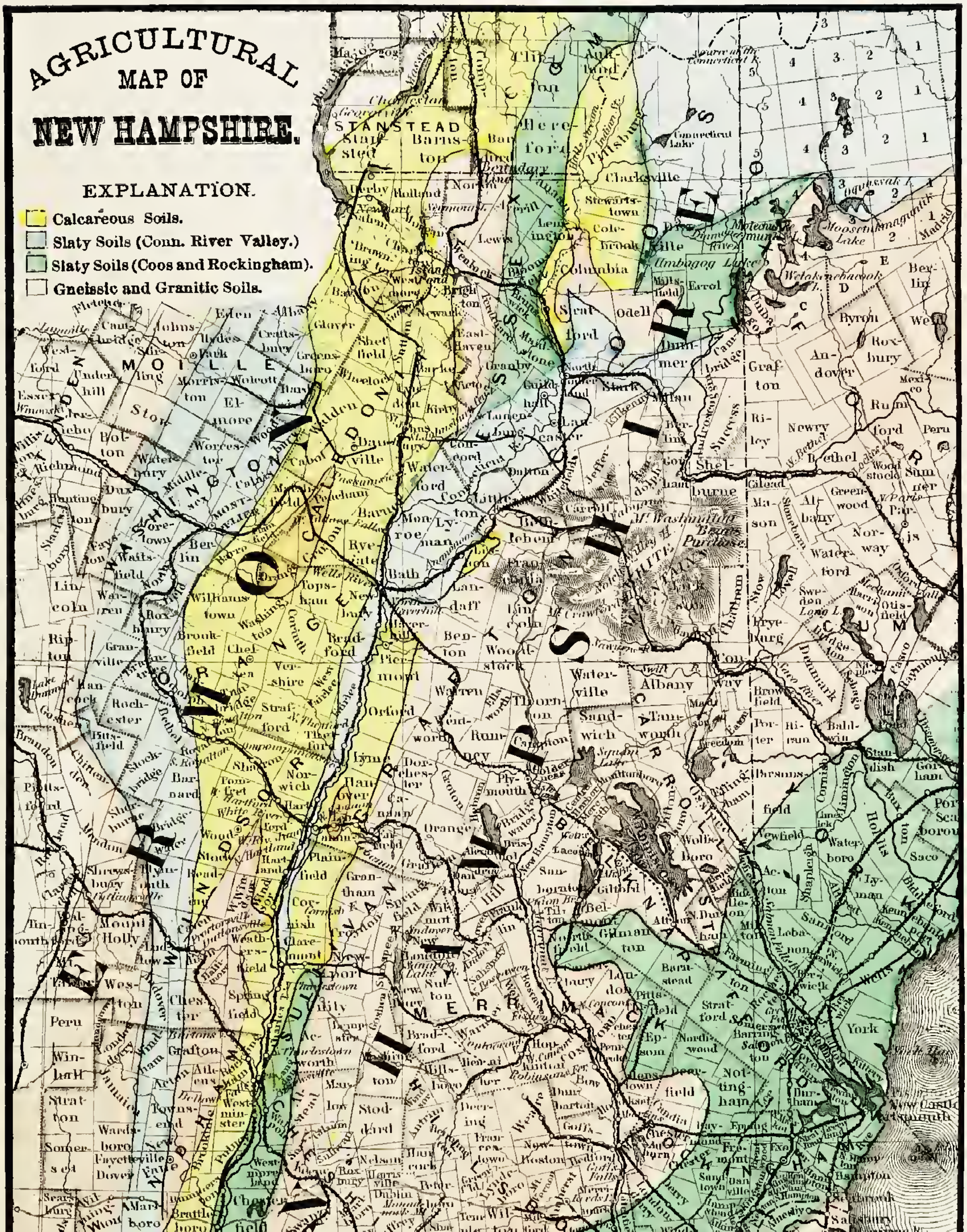
The soils of New Hampshire are divided into four kinds, upon the little map herewith presented. They are arranged in the order of their value. First, we have those derived from calcareous rocks, and exhibited in the Connecticut river valley near Colebrook and Claremont. Second, the balance of this hydrographic basin is occupied by more or less slaty and schistose rocks. These are somewhat calcareous, and decidedly magnesian. Third, the rocks bordering the coast in Rockingham county, and extending northerly up Piscataqua river, produce a very similar soil. Fourth, the rest of the state is underlaid by gneiss and granite, producing several grades of soil, according to particular local character.

In a subsequent chapter I shall show a map indicating what proportion of the state is now covered by a forest growth. By comparing this with the agricultural map, it will be easy for the pioneer to know where he can find the best virgin soil within our limits. The same map, and also one in Chapter XIII, shows what proportion of the state is situated above the limit of trees. Both these maps will be useful in studying the agricultural capacities of our domain. It was not desirable to incorporate the forest and the barren ground districts with the agricultural map, else comparisons of the kind of soil with the areas of wood-growth and arctic vegetation would have been impracticable.

The Calcareous Soils.

It is well known that the soils in eastern Vermont are of a superior character. I refer to those in the eastern part of Orleans county, most of Caledonia and Orange, and the eastern border of Windsor and Windham counties. These lands produce more in proportion to their valuation and inhabitants than the other districts east of the Green Mountains; and, as the climate and general topographical features are the same, the reason of their greater fertility must lie in the chemical character of the soil. Limestone countries are everywhere fertile.

The geological survey has been the first to discover the existence in New Hampshire of considerable areas of this formation. The ledges are composed of alternations of bluish siliceous limestone, clay slate,


AGRICULTURAL
MAP OF
NEW HAMPSHIRE.
EXPLANATION.
Calcareous Soils.
Slaty Soils (Conn. River Valley.)
Slaty Soils (Coos and Rockingham).
Gneissic and Granitic Soils.

and mica schist, which, by the action of the air, rain, and frost, readily decompose, and the lime and other fertile ingredients are leached out and diffused through the soil, where the roots of the growing crops can readily assimilate them. In consequence of this ready decomposition of the ledges, every small stream has excavated very much material; and this region is full of steep hills, often conical. These steep hillsides are fertile, as may be instanced in the towns of Cornish and Lyme.

Furthermore, there are considerations tending to show that the adjacent granite hills are benefited by the proximity of the limestones. The study of theoretical geology seems of little practical importance to many people; but, by examining scratches upon ledges, and other phenomena on the surface, we can say positively that immense masses of ice once travelled over the state in a general southerly direction (but varying greatly in different portions of the state). This ice, in its onward progress, broke off fragments of the ledges, and distributed them over the country. Hence, as the granite region lay in the path of this mighty stream, blocks of limestone came over its surface, and, by their decomposition, have tended to improve the soil. These may be found throughout the western border of the gneissic region from Dixville to Hinsdale.

Another benefit comes from the presence of the calcareous rocks. By their decomposition, numerous small molluscous animals are enabled to obtain the material for their shells. They consequently abound in calcareous countries, since they here find one of the essentials to their existence in great abundance. The aquatic tribes of mollusks exist in such great numbers that their remains accumulate at the bottom of ponds in deposits several feet thick. More than thirty of these beds are described in the geology of Vermont, in the region just spoken of. I have seen as yet only two in New Hampshire,—one in Columbia, and the other in Brookline. The lime is nearly pure, and can be burned for quick-lime, or spread upon the land fresh from the swamp. The pond-way has disappeared by filling up, and remains only as a swamp. The importance of these marl beds makes it desirable for those living upon the calcareous regions to search further. It would give me great pleasure to visit any deposit of this kind that may be discovered by the farmers within our state limits. The farmers will understand that lime and plaster are

not so essential to the growth of crops in the calcareous areas as elsewhere. Nevertheless, I have observed that where lime is the most abundant, the farmers are apt to use a great deal of it, even burning it for their own use from the ledges on their acres. If chemical analyses are reliable, we ought to find large returns of potatoes, peas, beans, clover, and rye from the calcareous area.

Besides the sources of lime mentioned, there are beds of the best quality of limestone for agricultural purposes in Plainfield, Lyme, Orford, Haverhill, Lisbon, Lyman, Littleton, and elsewhere. Nothing except a demand for the manufactured lime is necessary to cause the proprietors of these beds to produce this valuable mineral in large quantities.

Slaty Soils. Of the two, the slaty soils of the Connecticut valley are superior to those along the coast. The rock is apt to be a schist containing much alumina, a little lime and magnesia, and ten or twelve per cent. of soda and potassa; other members are soft slates, which are rich in alumina, and sometimes lime. The area south of Claremont is more apt to contain lime than potassa. When pulverized by the ice of the drift period, they give rise to beds of clay. The second class of slaty soils receives many boulders of granite through ice transportation, which are not so beneficial as the lime brought into the Connecticut valley from Vermont and Canada.

Granitic Soils. The greater portion of the state is underlaid by gneiss. This is practically the same as granite;—so that the words granite and gneiss convey the same meaning, so far as mineral composition is concerned. I think that the gneiss is apt to produce better soils than granite. The soluble element present is usually potash, from ten to twelve per cent. This is certainly a very valuable substance to be added to the soil; and nature is crumbling down the granites continually. It is done by the action of the atmosphere. The burning of wood and coal sends out carbonic acid. Whatever of this is not utilized by growing plants is left in the air to be dissolved in rain-water. The rain soaks into the rocks, and thus the acid acts upon the feldspars, setting free the potash, perhaps combining with it to form the carbonate (or saleratus). Should this mix with earth, the result will be beneficial to the crops. I doubt not that the pulverization of granite will benefit soils. No one could expect to accomplish great things in this way, since the decompo-

sition is gradual; but it would seem as if the constant destruction of granites, by hammers and fires, would, in the course of years, tend to remove unsightly rocks, and to improve the soil.

Several varieties of soil occur in the granitic region. High up many of the mountains the granites are bare, and allow little place for the accumulation of organic matter. When the valleys are wide, the better

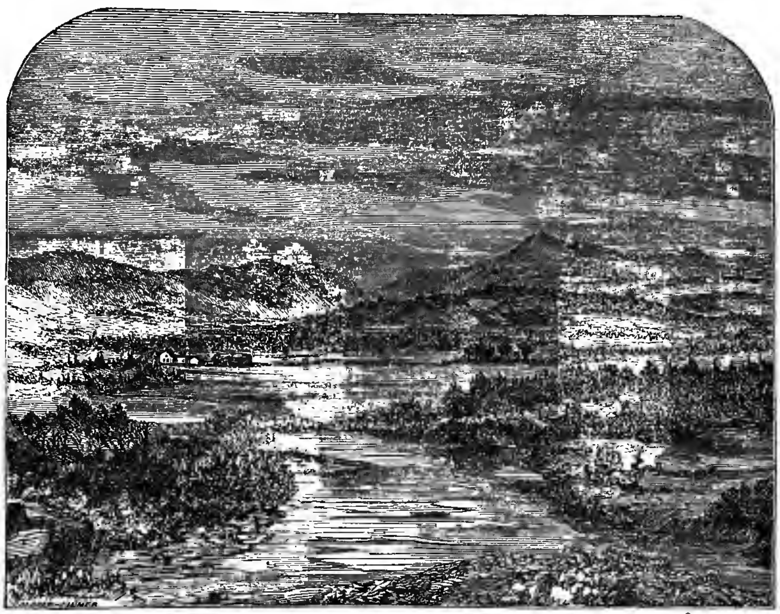


Fig. 66—FRANCONIA MOUNTAINS, FROM CAMPTON, PEMIGEWASSET RIVER IN THE FOREGROUND.

part of the rock and other substances accumulate, as in Fig. 66; so that after a while many farmers find they can allow their hills to revert to timber, and cultivate the original bogs and swamps with better success. Again, the soil is mixed, in consequence of the abundance of diverse drift material. This is generally an improvement. Another variety is found in the sandy plains of Carroll county, and the high terraces along the Merrimack. The current of ancient times was just strong enough to wash away the coarser particles into deposits by themselves, leaving the finer particles to form clays. An instance of this segregation is seen at Hooksett, where this clay is used for bricks, while the sand is accumulated in piles by itself.

The exact Composition of our Soils.

In addition to our general description of the soils of the state, it may be desirable to present analyses of them from different localities. Dr. Jackson, in his final report, gave the results of a large number, which I will reproduce in the form of a table. In analyses made at the present day, greater attention is paid to the determination of phosphoric acid, the alkalies, and nitrogenous compounds, than appears to have been devoted to the subject by Dr. Jackson. The table will show the average composition of the soils of the state, in respect to insoluble silicates, the peroxide of iron, alumina, lime and its compounds, magnesia, and the organic matter. The column stating the percentage of water is not of any practical importance. In a few cases special determinations were made of the organic matter, the following being invariably present: "(1) Crenic acid and crenates of bases; (2) apocrenic acid, combined also with bases; (3) humic acid, combined also with bases; (4) humic, or neutral undecomposed vegetable matter; (5) extract of humus, and (6) a second extract, not yet named, separated from the above; (7) phosphoric acid in minute quantities."

Analyses of Soils by Dr. Jackson.

Location.	Fragments more than 1/8 inch in size.	Fragments between 1/8 and 1-50 inch.	Fragments less than 1-50 inch.	Insoluble silicates.	Peroxide of iron.	Alumina.	Lime.	Salts of lime.	Magnesia.	Water.	Alkalies.	Organic matter.	Total.
Gov. Page's farm, Haverhill.													
No. 1, high interval soil,		.50	99.50	84.4	3.3	4.8		1.3		1		3.7	98.5
No. 2, meadow soil, annually flowed,	.60	1.60	97.80	81	5	4.9	1.4			2.2		5	99.5
No. 3, Benton flats, newly cultivated,	.40	1.40	98.20	13.8	5.1	5		.9		4.3		70.8	99.9
No. 4, upland, Haverhill corner,	7.80	13	79.20	81.2	3.3	4.5		1.1		2.8		7.5	100.4
First terrace, Charlestown,	2	8	90	81	4.5	4		4		2.4		4.2	100.1
Second terrace, do.	2.50	20.50	77	78	4.6	4.3		.1		3.4		8.1	99.4
Third terrace, do.	3	8.60	88.40	79.2	7.3	5.1		.3		3.2		5	100.1
Upper interval, Orford,		6.20	93.80	80.7	3.5	4.5		.9	.24	3.5		6.7	100.04
Upland soil, do.	15.30	18.40	66.30	76.7	5.3	4.2		1	.4	3.7		9.2	100.5
Lower interval, do.		.40	99.60	82.2	3.9	3.2		1.6	.4	2.7	Trace soda	5.8	99.8
Enfield Shakers' farm, Canaan,		.40	99.60	86.7	4.9		.6			4.5		2.3	99
Cultivated soil, E. Bailey, Acworth,	16.50	11	72.50	76.6	4	3		.9		4.9		9.6	99
E. Bailey's farm, Acworth,	15.40	24.30	60.30	77.6	4.5	3.4		.3	.44	5.2		8.3	99.74
Mr. Wells's farm, Lancaster,	9.70	12.90	77.40	79.5	5.5	3.6	.3			4.4		7.3	100.6

Location.	Fragments more than 1/8 inch in size.	Fragments between 1/8 and 1-50 inch.	Fragments less than 1-50 inch.	Insoluble silicates.	Peroxide of iron.	Alumina.	Lime.	Salts of lime.	Magnesia.	Water.	Alkalies.	Organic matter.	Total.
Dr. Jarvis's farm, Claremont, exhausted soil,	2.40	9	88.60	84.4	3.6	2.9		1	.1	3		4.9	99.9
Dr. Jarvis's farm, Claremont, fertile soil,	20	9.50	70.50	81.5	3.8	4		.8		3.3		6.5	99.9
Putnam's farm, Lyndeboro',	23	7	70	76.8	6		.4			4.4		9.6	97.6
do. turnip field,	30	23	47	75.2	6.4		3			5.4		8.8	100.8
Thos. Fisk, grass land, Dublin, No. 1,				77.6	8			.4	Ph'sp'te, .6	3.8		8.6	99
Thos. Fisk, etc., No. 2,				84.4	6.8			.3	.8	1.8	Traces	5.4	99.50
do. do. 3,				76.2	10.8			.6		5.6		5.4	98.60
do. do. 4,				80.4	9			1.4	.3	3.2		7	101.30
Cow island, Winnipiseogee lake, rich,	20	27.50	52.50	83.60	4.1	1.40		.7		2.7	P't'sh, .40	7.1	100
Long island, do. poor,	30	19.50	50.50	86.75	2.6	3.15		.5	.2	2		4.8	100
do. do. good,	9	26	65	80.80	2.2	4		.4	Trace.	3.9		8.7	100
J. Coe, Center Harbor, never manured,				88	2.5	3.3		.5	.25	1.7		3.6	99.85
Shaker farm, Canterbury, garden,				77.20	3.3	2.8	1.8		1	4.5		9.9	100.5
Shaker farm, do., subsoil, poor land,				90.20	2.2	3		.2	Trace.	1.6		2.88	100.08
Skaker farm, do., best natural grass land,				81.60	3	2.3		.1	.12	2.75		10.05	99.92
J. P. Stickney, upper alluvion of Merrimack, Concord,	1.50	10	88.50	77.40	3.6	4.5		1.2	.2	3.9		9.3	100.1
J. P. Stickney, lower allnvion,		5	95	79.90	3.5	4.4		.9	.3	3.2		7.5	99.7
Micaceous soil, Levi Bartlett's farm, Warner,				79.20	5.6		3.2		1.2	3.6	P't'sh, 2.2 soda, 2.5	1.8	99.3
Soil from do.,	5	3.60	95.90	85.50	8	2.7	.6			1.3		2.5	100.6
Hon. T. Chandler's farm, Bedford.													
Old field,				90.4	1	4.8	.4					4.4	101
Exhausted,				90	2.2	3	.7					4.5	100.4
From swamp,				18.5	2.3		3.5					76	100.3
W. Patten's farm, Bedford.													
Long cultivated, poor,	2.7	5.8	91.5	91.4	1.4	3		1				4	100.8
Long cultivated,	2	6.6	91.4	87.4	1	4		1.4				6	99.8
Sour land, never plowed,	1.2	2.6	96.2	87.4	.8	2.6	.6					8	99.4
Poor,	1.2	4.3	94.5	83.6	1.6	4.6	1.4					9	100.2
Swamp muck,				3.8	.8	.6	1					93	99
Muck,				1.8	.8	1	.6			5.8	Potash traces	89.6	96.6

Miscellaneous Analyses.

Location.	Silica.	Alumina.	Iron.	Carbonate lime.	Salts of lime.	Magnesia.	Water.	Organic matter.	Ash.	Total.
Dark brown peat, Shaker farm, Canterbury,	20.60		1.3	.7			13.7	62.9		99.2
Peat from same farm,	3.90	1.1			1.2			93.8		100
Peat, Magoon's farm, Lyndeborough,	4.7	2.3			5.4		21	66.7		100.1
Peat, do., when applied, and plants do poorly,							15	82.6	2.4	100
Peat, when applied, and plants thrive,							15.4	78	6.6	100
Peat, Franconia,	18.3		4		3.8	2		73.7		100
Peat, Meredith,	2.1	1			2			94.9		100
Marl, Hanover,	83		10	2.2				4.8		100
Clay marl, Brattleboro',	28	4.2	2	56.6			4.6	4.2		99.6
Clay, Piermont,	83.2		8.8	3.4			.6	3		99
Marl, Lyme,	79.5	5.1	4.3	7.3			1.1	2.8		100.1
Blue clay, Bath,	81.2	5	6.7		1.7		1.8	3.5		99.9

Dr. Jackson prepared an extensive sketch of the relations of geology to agriculture, to which the attention of those interested in the subject is invited, on account of the many valuable suggestions contained in it.

Use of Fertilizers.

Formerly it was thought that the mineral constituents of plants were of no great consequence in their growth. Experimental research indicates that certain proportions of various mineral elements are essential to the perfect growth of a plant, and that if the proper ash-constituents are not supplied, every part may be vigorously developed except the seed. These researches have led to the extensive introduction of mineral fertilizers.

In order to understand what kind of fertilizers should be applied to the soil, the farmer should know, first, the exact composition of his ground; second, of his crops; and third, of the proper fertilizers to be applied. The statements already given will show in general the composition of the soils of the state. For more exact information, special determinations should be made in each case. It will be possible to present a few general statements in respect to the composition of the more common farm products and commercial fertilizers. These analyses will be a safe guide when one wishes to know what fertilizers must be applied to the soil in order to restore what has been abstracted from it by the removal of the several crops. The tables are derived from an essay on

Substances.	Total ash.	Nitrogen.	Potassa.	Soda.	Lime.	Magnesia.	Phos. acid.	Sulph. acid.	Silicic acid.
Wheat grain,	17.7	20.8	5.5	.6	.6	2.2	8.2	.4	.3
Rye grain,	17.3	17.6	5.4	.3	.5	1.9	8.2	.4	.3
Barley grain,	21.8	15.2	4.8	.6	.5	1.8	7.2	.5	5.9
Oat grain,	26.4	19.2	4.2	1	1	1.8	5.5	.4	12.3
Corn grain,	12.3	16	3.3	.2	.3	1.8	5.5	.1	.3
Pease,	24.2	35.8	9.8	.9	1.2	1.9	8.8	.8	.2
Beans,	29.6	40.8	12	.2	1.5	2	11.6	1.5	.4
Potatoes,	9.4	3.2	5.6	.1	.2	.4	1.8	.6	.2
Common beet-roots,	8	1.8	4.3	1.2	.4	.4	.8	.3	.2
Turnips,	7.5	1.8	3	.8	.8	.3	1	1.1	.2
Hay,	66.6	13.1	17.1	4.7	7.7	3.3	4.1	3.4	3.4
Live calf,	38	25	2	.6	16.3	.5	13.8		.1
Live oxen,	46.6	26	1.7	1.4	20.8	.6	18.6		.1
Live sheep,	31.7	22.4	1.5	1.4	13.2	.4	12.3		.2
Live pig,	21.6	20	1.8	.2	9.2	.4	8.8		
Wool (washed),	10.3	94.4	1.9	.3	2.5	.6	.3		.3
Milk,	7	6.4	1.7	.7	1.5	.2	1.9	.1	
Cheese,	67.4	45.3	2.5	26.6	6.9	.3	11.5		
Eggs,	84.8	21.8	1.6	1.5	43.3	.3	3.2		

commercial fertilizers by Prof. C. A. Goessmann, in the tenth annual report to the Massachusetts Agricultural College, January, 1873.

The first table shows the amount and kind of plant-food contained in one thousand pounds of various air-dried substances.

Stable manure is one of the most important fertilizers,—yet its peculiar value depends more on its influence upon the physical condition of the soil than its chemical composition. The following statement will show its chemical character in various stages of disintegration. One thousand pounds contained (Wolff.),—

	Water.	Organic substances.	Ash (total).	Nitrogen.	Potassa.	Soda.	Lime.	Magnesia.	Phos. acid.	Sulph. acid.	Silicic acid.	Chlorine.
When fresh, ...	710	246	44.1	4.5	5.2	1.5	5.7	1.4	2.1	1.2	12.5	1.5
When half decomposed, . .	750	192	58	5	6.3	1.9	7	1.8	2.6	1.6	16.8	1.9
When more decayed, .	790	145	65	5.8	5	1.3	8.8	1.8	3	1.3	17	1.6

The following analyses by Dr. Goessmann were made from samples taken from the original packages in which they were placed for sale by the manufacturers. As the farmer does not propose to pay for anything but phosphoric acid, nitrogen (or ammonia), and potassa, the results are given with particular reference to these substances. The valuation of these articles has been made in conformity with the prices of late recognized by dealers and consumers in our section of the country. These prices are 16.25 cents for each pound of soluble phosphoric acid, 13.2 cents for every pound of reduced phosphoric acid, 6 cents for every pound of insoluble phosphoric acid, 30 cents for each pound of nitrogen, and 8 cents for each pound of potassa. Reduced phosphoric acid is that portion which has apparently once been rendered soluble in water, but has become insoluble again in consequence of peculiar reactions which sometimes occur in the manufactured fertilizer. Its compound with lime is soluble in citrate of ammonia, and in a suitable condition for speedy absorption under the influence of the carbonic acid of the soil.

I.

AMMONIATED BONE SUPERPHOSPHATE OF LIME, MANUFACTURED BY RUSSELL & CO.

Moisture and volatile matter, ... 61.54 per cent.

Non-volatile matter,	38.46 per cent.
Soluble phosphoric acid,	10.55 "
Reduced phosphoric acid,	2.14 "
Insoluble phosphoric acid,	2.46 "
Nitrogen (=2.5 ammonia),	2.02 "

Valuation per ton of 2000 *pounds.*

211.0 pounds of soluble phosphoric acid,	$34.24
42.8 pounds of reduced phosphoric acid,	5.60
49.2 pounds of insoluble phosphoric acid,	2.95
40.4 pounds of nitrogen (50.0 pounds of ammonia),	12.12
	$54.91

II.

W. L. BRADLEY'S XL FERTILIZER.

Moisture and volatile matter,	52.11 per cent.
Non-volatile matter,	47.89 "
Soluble phosphoric acid,	6.45 "
Reduced phosphoric acid,	2.83 "
Insoluble phosphoric acid,	3.60 "
Nitrogen (3.23 ammonia),	2.43 "

Valuation per ton of 2000 *pounds.*

129.0 pounds of soluble phosphoric acid,	$20.96
56.6 pounds of reduced phosphoric acid,	7.47
72.0 pounds of insoluble phosphoric acid,	4.32
48.6 pounds of nitrogen (64.6 ammonia),	14.58
	$47.33

III.

WILSON'S AMMONIATED SUPERPHOSPHATE OF LIME.

Moisture and volatile matter,	50.95 per cent.
Non-volatile matter,	49.05 "
Soluble phosphoric acid,	6.65 "
Reduced phosphoric acid,	1.01 "
Insoluble phosphoric acid,	0.93 "
Nitrogen (3.42 ammonia),	2.82 "

Valuation per ton of 2000 *pounds.*

133.0 pounds of soluble phosphoric acid,	$21.51
20.2 pounds of reduced phosphoric acid,	2.66
18.6 pounds of insoluble phosphoric acid,	1.12
56.4 pounds of nitrogen (68.4 ammonia),	16.80
	$42.09

IV.

Quinnipiac Soluble Nitrogenous Phosphate.

Moisture and volatile matter,	55.51	per cent.
Non-volatile matter,	44.49	"
Soluble phosphoric acid,	5.50	"
Reduced phosphoric acid,	2.45	"
Insoluble phosphoric acid,	3.47	"
Nitrogen (3.14 ammonia),	2.59	"

Valuation per ton of 2000 *pounds.*

110.0 pounds of soluble phosphoric acid,	$19.87
49.0 pounds of reduced phosphoric acid,	6.67
79.4 pounds of insoluble phosphoric acid,	4.76
51.8 pounds of nitrogen (62.8 ammonia),	15.54
	$46.74

V.

Fale's Fertilizer.

Moisture and volatile matter,	39.87	per cent.
Non-volatile matter,	60.13	"
Soluble phosphoric acid,	1.50	"
Reduced phosphoric acid,	2.49	"
Insoluble phosphoric acid,	4.06	"
Nitrogen (3.23 ammonia),	2.66	"

Valuation per ton of 2000 *pounds.*

30.00 pounds of soluble phosphoric acid,	$4.88
49.80 pounds of reduced phosphoric acid,	6.57
81.20 pounds of insoluble phosphoric acid,	4.87
53.20 pounds of nitrogen (64.6 ammonia),	15.96
	$32.28

VI.

Guano (Guanape Islands).

Moisture and volatile matter,	57.38	54.17	54.98
Non-volatile matter,	42.62	45.83	45.02
Sand,	10.94	12.47	13.10
Total phosphoric acid,	11.59	12.08	11.25
Nitrogen (11.78 ammonia),		9.70	
Potassa,		2.02	

Valuation per ton of 2000 *pounds.*

238.80 pounds of phosphoric acid (at 12.64 cents per pound),	$30.18

194.00 pounds of nitrogen (235.60 ammonia), ...	$58.20
40.40 pounds of potassa, ...	3.23
	$91.61

By studying these tables the farmer can know what fertilizers are most important for producing required products, and also whether the price required for these fertilizers is reasonable.

The great amount of matter pressing upon us for presentation makes it necessary to defer any further notice of the relations of geology to agriculture.

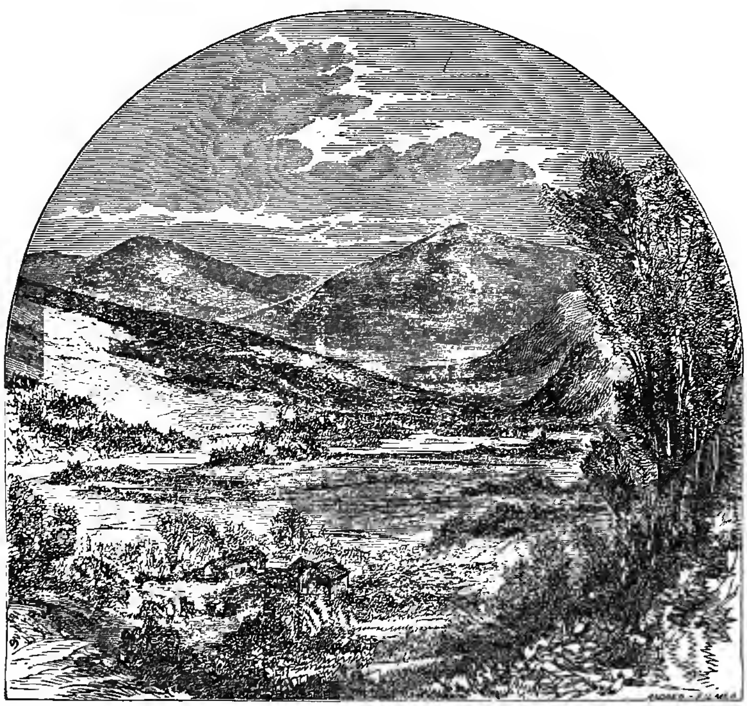


Fig. 67.—MADISON AND WASHINGTON, FROM SHELBURNE.

CHAPTER XVII.

REMARKS UPON THE DISTRIBUTION OF ANIMALS AND PLANTS.

THE object of this chapter is to present a few additional facts respecting the distribution of animals and plants, and endeavor to deduce from all that is known the precise boundaries between the Canadian and Alleghanian districts; and to call the attention of botanists to the importance of drawing the lines between the alpine and sub-alpine floras. The determination of these questions requires the application of a knowledge of our isothermal lines,—both for summer and winter temperature,—the contour lines of elevation above the sea, and the actual limits of the distribution of the principal animals and plants.

THE DISTRIBUTION OF BIRDS.

From the writings of prominent ornithologists, it is now possible to ascertain the geographical limits within which the different species of birds rear their young. On account of their migratory habits, the birds are reckoned to belong to those regions where they breed. Very many arctic birds are seen within our limits, especially during the winter, but these are not to be classed among New Hampshire birds. The lists herewith appended are not exhaustive; but I have taken pains to present only those names which are stated to breed within our limits, by competent authorities. It will be quite desirable to collect facts respecting the breeding of birds along the Connecticut-Merrimack water-shed, since certain Canadian species may be found farther south along this line than has been heretofore supposed.

Birds not breeding south of the limits of the Canadian Fauna in New Hampshire.

Accipiter Cooperi Bon. Cooper's Hawk.
Aquila Canadensis Cass. Golden eagle.
Picoides hirsutus Gray. Banded three-toed woodpecker.
Contopus borealis Baird. Olive-sided fly-catcher.
Empidonax Traillii Baird. Traill's fly-catcher.
E. flaviventris Baird. Yellow-bellied fly-catcher.
Turdus Swainsonii Cab. Olive-backed thrush.
Regulus satrapa Licht. Golden-crowned wren.
Geothlypis Philadelphia Baird. Mourning warbler.
Helminthophaga ruficapilla Baird. Nashville warbler.
H. peregrina Cab. Tennessee warbler.
Dendroica Canadensis Baird. Black-throated blue warbler.
D. coronata Gray. Yellow-rumped warbler.
D. Blackburniæ Baird. Mrs. Blackburne's warbler.
D. castanea Baird. Bay-breasted warbler.
D. maculosa Baird. Black and yellow warbler.
Perissoglossa tigrina Baird. Cape May Warbler.
Myiodioctes Canadensis And. Canada Fly-catching warbler.
Troglodytes hyemalis Vieill. Winter wren.
Chrysomitris pinus Bon. Pine finch.
Curvirostra Americana Wils. Cross-bill.
Junco hyemalis Sclater. Blue snow-bird.
Guiraca Ludoviciana Sw. Rose-breasted grosbeak.
Scolecophagus ferrugineus Sw. Rusty grackle.
Perisoreus Canadensis Bonap. Canada Jay. Meat bird.
Tetrao Canadensis Linn. Spruce partridge.
Ryacophilus solitarius Baird. Solitary sandpiper.
Bucephala Americana Baird. Whistler.
Lophodytes cucullatus Reich. Hooded Merganser.
Larus argentatus Brunn. Herring Gull.

Most characteristic of the Birds breeding in the limits of the Alleghanian Fauna, and chiefly those which rarely show themselves beyond their breeding-grounds towards the north.

Accipiter fuscus. Sharp-shinned hawk.
Buteo borealis Vieill. Hen hawk.
Buteo lineatus Jard. Red-shouldered hawk.
Buteo Pennsylvanicus Bon. Broad-winged hawk.
Circus Hudsonius Vieill. Marsh hawk.

Otus Wilsonianus Les. Long-eared owl.
Coccygus Americanus Bon. Yellow-billed cuckoo.
Coccygus erythrophthalmus Bon. Black-billed cuckoo.
Melanerpes erythrocephalus Sw. Red-headed woodpecker.
Trochilus colubris Linn. Humming-bird.
Sayornis fuscus. Baird. Pewee.
Dendroica virens Baird. Black-throated green warbler.
Dendroica Pennsylvanica Baird. Chestnut-sided warbler.
Myiodioctes pusillus Bon. Wilson's black-cap fly-catcher.
Vireo gilvus Bon. Warbling fly-catcher.
Mimus Carolinensis Gray. Cat-bird.
Harporhynchus rufus Cab. Brown thrush.
Troglodytes ædon Vieill. House wren.
Spizella monticola Baird. Tree sparrow.
Spizella pusilla Bon. Field sparrow.
Spizella socialis Bon. Chipping sparrow.
Cyanospiza cyanea Baird. Indigo bird.
Pipilo erythrophthalmus Vieill. Towhee bunting.
Dolichonyx oryzivorus Sw. Bobolink.
Molothrus pecoris Sw. Cow blackbird.
Icterus Baltimore Daud. Baltimore oriole.
Cyanura cristata Sw. Blue jay.
Actiturus Bartramius Bon. Field plover.

Birds breeding within the supposed limits of the Canadian Fauna in New Hampshire, and also within the Alleghanian area.

Bubo Virginianus Bon. Great-horned owl.
Scops asio Bon. Mottled owl.
Syrnium nebulosum Gray. Barred owl.
Nyctale Acadica Bon. Acadian owl.
Astur atricapillus Bon. Goshawk.
Haliætus leucocephalus Savig. Bald eagle.
Picus villosus Linn. Hairy woodpecker.
Picus pubescens Linn. Downy woodpecker.
Sphyropicus varius Baird. Yellow-billed woodpecker.
Hylatomus pileatus Baird. Pileated woodpecker.
Colaptes auratus Sw. Golden-winged woodpecker.
Chætura pelasgia Steph. Chimney swift.
Antrostomus vociferus Boie. Whip-poor-will.
Chordeiles popetue Bd. Night-hawk.
Ceryle alcyon Boie. Belted kingfisher.
Tyrannus Carolinensis Baird. Kingbird.

Contopus virens Cab. Wood pewee.
Empidonax minimus Baird. Least fly-catcher.
Turdus migratorius Linn. Robin.
Turdus fuscescens Steph. Wilson's thrush.
Turdus Pallasii Cab. Hermit thrush.
Sialia sialis Bd. Blue-bird.
Parula Americana Bon. Blue yellow-backed warbler.
Geothlypis trichas Cab. Maryland yellow-throated warbler.
Seiurus aurocapillus Sw. Golden crowned thrush.
Seiurus Noveboracensis Nutt. Water thrush.
Setophaga ruticilla Sw. Redstart.
Hirundo horreorum Bart. Barn Swallow.
Petrochelidon lunifrons Bd. Cliff swallow.
Tachycineta bicolor Cab. White-bellied swallow.
Cotyle riparia Boic. Bank swallow.
Progne rubis Bd. Purple martin.
Ampelis cedrorum Baird. Cedar bird.
Vireo olivaceus Vieill. Red-eyed Vireo.
Vireo solitareus Vieill. Solitary Vireo.
Certhia familiaris Linn. Brown creeper.
Sitta Carolinensis Gm. White-bellied nut-hatch.
S. Canadensis Linn. Red-bellied nut-hatch.
Parus atricapillus Linn. Black-capped Titmouse. Chickadee.
Carpodacus purpureus Gray. Purple finch.
Chryromitris tristis Bon. Gold-finch. Yellow-bird.
Passerculus savanna Bon. Savannah sparrow.
Pooecetes gramineus Baird. Grass finch.
Zonotrichia albicollis Bon. White-throated sparrow.
Melospiza melodia Baird. Song sparrow.
M. palustris Baird. Swamp sparrow.
Agelæius phœniceus Vieill. Red-winged blackbird.
Quiscalus versicolor Vieill. Crow blackbird.
Corvus Americanus Aud. Crow.
Ectopistes migratorius Swain. Wild pigeon.
Bonasa umbellus Steph. Partridge.
Ardea herodias Linn. Great Blue heron.
Botaurus lentiginosus Steph. American bittern.
Philohela minor Gray. Woodcock. Rare.
Tringoides macularius Gray. Spotted sandpiper.
Anas obscura Gm. Black duck.
Aix sponsa Boie. Wood duck.
Colymbus torquatus Brunn. Loon.

THE DISTRIBUTION OF INSECTS.

At my request, Mr. C. P. Whitney, of Milford, visited the southern part of Cheshire county, in the early part of August (1874), with the view of ascertaining whether some of the more northern species of insects extended farther south than the latitude of Milford. The season proved to be an unfavorable one for observing characteristic species, partly because of stormy weather, and partly because the most peculiar forms usually make their appearance earlier in the summer.

Concerning the fauna of Mt. Monadnock, Mr. Whitney writes,—"Although about the summit I found flora corresponding to the sub-alpine of the White Mountains, I met with no insects except such as are found below, and of those but few."

Concerning the insects south of the mountain he writes,—"To the south of the mountain in Jaffrey, Rindge, etc., I found *Minois Alope* (which I can hardly regard as Canadian) in abundance; also, *Basilarchia Arthemis, Grapta Faunus (Polygonia* of Scudder), *J. album, A. bombyx,* and *Ctenucha Virginica.*

"Although owing to the continued rainy weather I met with but little success, I am satisfied those towns possess a more northern fauna than Milford and its vicinity,—whether enough so to place them in the Canadian region (if, indeed, a division is practicable), I cannot determine.

"I wish to call your attention to a few instances which conflict more or less with Mr. Scudder's text. The numbers are those of his list.

"4. *Nephele* is not found in the southern part of the state.

"11. Mr. Hutchinson has taken a specimen of *interrogationis* at Hanover.

"24. I have seen *Aphrodite* in the sub-alpine region of Mt. Washington.

"35. *Edwardsii* has never been taken here [Milford].

"69. *Vialis* is common in the lowlands of this vicinity; and I have found it abundant both in the Glen (White Mountains) and at Dixville notch, in the northern extremity of the state.

"71. *Paniscus (Mandan)* I have taken at Colebrook; and Mr. Morrison took one specimen in the Glen.

"73. *Massasoit* has not been seen here.

"81. *Manataaqua* is found here occasionally.

"84. *Verna* has never been taken in this vicinity.

"*Œcanthus niveus*, *Phylloptera oblongifolia*, and *Arphia sulphurea* are common here."

THE DISTRIBUTION OF PLANTS.

I have quite a number of additional facts to present upon the distribution of plants, and will notice, first, certain features of the maritime species; then of the alpine forms; and afterwards remark upon the areas covered by forests.

Maritime Plants.

The catalogue of plants gives the names of thirty-seven species frequenting the sea-shore, and six more will probably be discovered within our limits. Botanists suppose, as these plants are mainly confined to the neighborhood of the ocean, that the impregnation of the atmosphere, and perhaps soil, with saline materials determines their habitat. It happens that many of them occur in connection with salt deposits in western New York, etc.; along the St. Lawrence river and the great lakes, and in saline regions among the Rocky Mountains. A little reflection upon the facts that will be presented will show that the distribution of these maritime plants in North America may be a proof of oceanic submergence in the period intervening between the age of ice and historic time.

American botanists have frequently recorded the presence of maritime phenogamous plants in the interior of the continent, and have commented upon the singularity of the circumstance. For example, Prof. J. A. Paine, Jr., in the *Regents' Report of the New York State Cabinet* for 1865, enumerates *Juncus Balticus* among the plants of Genesee county, at a locality over three hundred feet above Lake Ontario, and twenty miles south of it, associated with *Zygadenus glaucus* and *Solidago Houghtonii*, found only on the north shore of Lake Michigan. It is a sea-side plant, native in the northern European and American coasts. "For its introduction to the great lakes it is just as dependent on the ocean as are *Ranunculus Cymbalaria*, *Atriplex hastata*, *Salicornia herbasea*, *Najas major*, *Ruppia maritima*, *Trigoclin maritimum*, *Juncus*

bulbosus, *Scirpus maritimus*, and *Spartina stricta*, for their existence at Onondaga lake, and *Lathyrus maritimus* on the banks of Oneida lake." He then conjectures that in some past geological period the land was submerged, and the ocean extended into the interior.

In the *Canadian Naturalist* for May, 1867, A. T. Drummond, B. A., LL.B., sets forth similar facts, and mentions twenty species of maritime plants that have been found in the interior. He refers the origin of this distribution to the presence of salt water in the great lakes in the Post-Pliocene or Champlain period, subsequent to the glacial drift. As the waters gradually became fresh, some of the species would be exterminated, and others become reconciled to the changed conditions, and remain as monuments to this ancient oceanic prolongation into the interior of the continent.

A few years since I made inquiries of botanists for catalogues of plants along the great lakes, St. Lawrence and Hudson river valleys, and published in the *Proceedings of the American Association for the Advancement of Science** a brief statement of the facts obtained, with details respecting the occurrence of the species in the several localities.

There are seventy-nine species in this list. Of these, seven are noted as doubtful, since they may not be confined in their range to the sea-shore. The following may be legitimately added to the doubtful list: *Zygadenus glaucus*, *Solidago Houghtonii*, and *Corispermum hyssopifolium*. These occur in the interior, and not on the coast. The last, with *Najas major*, are not on the American, but flourish on the European coast. Add, also, *Lobelia Kalmii*, *Rhyncospora capillacea*, *Scleria verticillata*, *Scirpus pungens*, and *Polanisia graveolens*, which, upon a careful examination, may prove to belong to the maritime type;—certainly, so far as known, their distribution corresponds with that of the seventy-nine in the table. These eight, added to the seventy-nine, make a total of eighty-seven.

Of this list, following *Gray's Manual of Botany*, twenty-two are found on the coast north of New York, six south of the same, thirty (including *Juncus Vaseyi*, on the authority of Dr. T. C. Porter) occur mostly south of New England, and twenty-two are found along the whole of our eastern shore. Thirty-three of them, or only ten less than the whole number

* Vol. xix, p. 175.

occurring on the coast north of New York, are found in the interior, distributed as follows: Lower St. Lawrence waters, five; Lake Ontario, nine; salt region of western New York, seventeen; Lake Erie, seventeen; Lake Huron, twelve; Lake Michigan, fourteen; Lake Superior, fifteen; Minnesota, seven; Hudson river, only one; Lake Champlain, three; and Hudson's bay, three.

Theory. The proper explanation of the distribution of maritime plants has been already shadowed forth in the comments of Messrs. Paine and Drummond. Following the glacial period, geologists believe the land of northern America has been submerged several hundred feet, as shown by the remains of marine animals. Along our coast this submergence exceeded one hundred feet. The proof of this statement will be given under the head of Surface Geology. The St. Lawrence valley has yielded marine shells at the height of 470 feet at Montreal, and at somewhat lower elevations in Ontario. When the St. Lawrence valley was thus covered by salt water, the maritime plants would naturally creep along the shore; and thus may be explained with certainty their introduction as far as the basin of Lake Ontario. So far, the explanation must be satisfactory, especially since no conclusions are involved that cannot be legitimately drawn from other sources.

If the theory is valid, it may be used to account for the introduction of maritime plants along Lakes Erie, Michigan, Huron, and Superior, and it is difficult otherwise to understand how they could have made their appearance in Minnesota. But Lake Superior is surrounded by terraces up to 330 feet, or 968 feet above the ocean. It is agreed that these terraces indicate former levels of water; and that the period of submergence was essentially coeval with that of depression along the sea border indicated by the fossils. The inference therefore seems legitimate that these high terraces were formed beneath the salt water which introduced the plants. If so, an argument is afforded of a submergence of the land about the great lakes of about one thousand feet. Fossil shells of the Champlain age have been found at the height of 1000 feet, on Cornwallis and Beechey islands in Arctic America; and it may be that the depression of the land was uniform over all the northern part of our continent at this time. But at present the arguments from the distribution of the maritime plants and the supposed requirements

of the terraces are all that can be relied upon to suggest so great a submergence.

From molluscan remains it is proved that the Hudson and Champlain valleys were covered by salt water in the period now under consideration. The proof of submergence, from the occurrence of maritime plants, is very meagre, only four species appearing on the list. It is possible that future researches may add to the list, though not in large numbers, after the researches of Oakes, Tuckerman, Torrey, Zadock Thompson, and Peck. It may likewise be observed that the lower St. Lawrence furnishes fewer species than the borders of the great lakes. These deficiencies were so patent, that Mr. Peck, in his reply to my inquiries, regarded "the connection between the maritime plants of the region of the great lakes with the Atlantic ocean, by intermediate stations, as not well shown." Is it not possible that these breaks in the connection are proofs of the correctness of our theory? If the continued existence of these plants about the lakes is due to the presence of large bodies of water, even in the absence of salt, then we should not expect to find them remaining along the narrow Champlain, nor the still narrower Hudson river, nor, to a large extent, the St. Lawrence. The conditions are not favorable to their preservation. Furthermore, if the species were equally distributed from the ocean into the interior, or especially if they became fewer in number the farther they penetrated the continent, it might be said that they had migrated, since the Champlain period, even to Minnesota. Hence what might appear destructive of our theory is in reality a strong argument in its favor. These considerations were forcibly set forth in a private communication from Dr. Ward.

It might be said by some that the plants in the salt regions of western New York existed there naturally on account of the presence of saline matters in the soil. This circumstance will not, however, explain their origin. During the glacial period all life was destroyed by the intense cold. Hence the salt-loving plants disappeared. With the return of the warm temperature, the plants could not return by an overland emigration. They could return only by a gradual migration along a shore line, whether salt or fresh, unless it be supposed plants were created for this special locality. The latter supposition is untenable, since a special creation is not required to explain the distribution of the other plants in

the Northern states; and we cannot suppose there would be any difference in the manner of the introduction of the two classes. Once introduced, the salt-loving plants would find a congenial habitat, and would not disappear, even after the removal of the estuary.

There is hardly a possibility that the seeds of these plants could have been preserved in the ground during the long ages of glacial cold, and revivified after the return of warmth. Besides, the glacier, in plowing out the valleys, would have transported these seeds far to the south, and fresh débris from the north would have covered up the briny exudations.

Botanists have described many maritime plants from the salt regions of the Rocky Mountains. These are the descendants of those which were introduced by oceanic migrations in Cretaceous or Tertiary times; and, as the glacier never covered them, they have continued uninterruptedly till now.

The distribution of certain forms of animal life confirms our theory. A species of marine crustacean has been found recently by Dr. William Stimpson, by dredging in the waters of Lake Michigan. Girard describes a fish from these northern lakes, *Triglopsis Thompsoni*, all whose affinities are marine. Add to these the oft-quoted instance of marine insects found on Lake Superior by Dr. Leconte, and a parallel case of the discovery of two species of *Mysis* in Norwegian lakes. Also, according to F. W. Putnam, director of the Peabody Museum, in Salem, Mass., the fishes found in Lakes Champlain and Erie are so much alike, though widely separated, that an ancient salt-water connection is needed to explain their present isolation.

Perhaps other evidences of a marine connection may be found in Lake Winnipiseogee. The fishermen are now familiar with a fresh-water smelt there, which is said to be the same species with the one so abundant in the ocean. This fact is certainly suggestive of a former connection between the lake and ocean.

The White Mountain Plants.

Concerning these I will present a few statements prepared by Dr. Nathan Barrows, of Meriden, at my request, and read before the Dartmouth Scientific Association, September 28, 1870.

The most interesting part of the botany of New Hampshire is that

of the White Mountains; and on our alpine summits, above the limit of trees, the vegetation is altogether peculiar.

About fifty-four plants are met with on the alpine summits of the White Mountains, which are found nowhere else in New England except on similar summits in neighboring states, and, in addition to these, probably enough species whose habitat is lower down find their way to the same region to make the number more than one hundred. On my recent visit to Mt. Washington and its neighbors, I made what observations on this subject my limited time allowed, noticing fifty-eight such species. These, added to the fifty-four truly alpine species, make one hundred and twelve species which I now know to be found above the limit of trees.

An enumeration of both divisions will be found appended. A thorough investigation of this subject would be of great practical value; and perhaps it has been made, though not within my knowledge.

Of these plants, at least thirteen species belong to the Ericaceæ, eleven to the Compositæ, seven to the Rosaceæ, four to the Caryophyllaceæ, three each to the Scrophulariaceæ and Polygonaceæ; while there are two birches, four willows, five rushes, thirteen sedges, and two club-mosses.

On the very summit of Mt. Washington are found in comparative abundance *Arenaria Grœnlandica*, *Poa laxa*, *Juncus trifidus*, and, where there is a little moisture, *Carex rigida*.

A little lower down, while descending the first steep, rocky sides of the highest peak, we begin to find in dry places *Potentilla trifida*, the two *Lycopodia*, *Diapensia Lapponica;* and, wherever there is a little more warmth and moisture, especially on the slope towards Tuckerman's ravine, the *Solidago*, some of the grasses, the dwarf *Cornus*, chickweed wintergreen, *Juncus filiformis*, and a variety of the *Carex canescens*, which grows abundantly throughout New Hampshire. We then begin to find the great variety of Alpine shrubs, most of which get along without much moisture, but where there is a moist spot, the Painted cup, Peck's *Geum*, the two species of *Nabalus*, and *Spiræa salicifolia*.

I found both the common sorrel *(Rumex acetosella)* and herds-grass *(Phleum pratense)* far up toward the summit.

Around the Lake of the Clouds may be found the willows and alpine birch, the alpine violet and bistort and cranberry, *Linnæa borealis*, the

common harebell, and many of those species which have already been mentioned; while at the head of Tuckerman's and other ravines we see the *Arnica*, *Epilobium*, *Veronica*, the grasses, willows, and alder; and, in certain limited localities, rare and local plants like the *Gnaphalium*, *Cardamine*, *Euphrasia*, *Rhinanthus*, and *Oxyria*.

I have aimed to give only a general idea of the manner in which plants are distributed on this one alpine summit, as my knowledge of the subject is too limited to attempt a thorough statement of localities. The whole mountain region of New Hampshire ought to be thoroughly studied with reference to the determination of the limits of species. A thorough botanical exploration of one such mountain as Washington, from base to summit, including an examination of every spur and ridge and ravine, would do more to advance botanical science and determine those influences which fix the limits of species than the same amount of time and labor expended in any other way. Moreover, there are portions of this region, as, for instance, Mt. Carrigain and its vicinity, which seem to have received as yet almost no attention; and I feel sure that in these solitudes many anxious plants still await names from their fortunate discoverer.

There are certain marked peculiarities of these alpine plants which are worthy of notice. First, they are all perennials, with the single exception of *Euphrasia officinalis*, and this, according to Tuckerman, is found only about the head of Oakes's gulf, quite far from the summit of Mt. Washington. Second, the size of individual flowers is in general remarkably large for the genus. We have thirty-nine species of *Solidago*. The *S. Virga-aurea*,—var. *alpina*,—is the largest of them all; and the next in size is *S. thyrsoidea*, which runs up as far as the Lake of the Clouds. These are the only ones found upon the summit. Peck's *Geum* has the largest flower of all the nine species of that genus. The flower of *Nabalus Boottii* is the largest in the nine species of that genus. The *Arnica mollis* is a large flower; *Poa laxa* is the largest flowered of our thirteen *Poæ;* and the same thing may be remarked of many of the ericaceous shrubs.

Another thing worthy of notice is the manner of growth of the alpine shrubs. Most of them, after rising a few inches, spread out abruptly, adapting themselves to the surface of any rock which may be near, thus

giving them support and warmth, and power to resist the fierce winds which frequent these regions. Even the firs at the heads of the ravines do the same thing, and, sometimes, where they grow thick together, after rising two or three feet above the rocks, they spread out with a flat surface, following the general slope of the ravine, and become so thickly interwoven that one with care may walk quite a distance on their surface, as upon a lawn,—yet if he do chance to slip through a treacherous opening into the apartments beneath, if will be some time,—if not longer, as I have found to my cost,—before he gets out again.

Another point of great interest in the study of our mountain flora is the large ratio of species common to it and Europe. Confining our inquiries to the strictly alpine plants, forty-two of fifty-three, or seventy-nine per cent., are common to both countries. This fact lends countenance to the hypothesis that the two countries were formerly much more intimately connected by means of a mountain chain than they are at present. I am not aware what the ratio of species common to the European and American floras as a whole is, but, remembering that in the inquiry we must confine ourselves to indigenous plants exclusively, it must be much less than twenty per cent. The disparity is from any point of view quite remarkable, and its cause worthy close investigation.

List of Plants found in New Hampshire only on Alpine Summits. Those found also in Europe are marked Eu; those marked with an asterisk (*) *were regarded by Asa Gray in* 1856 *as sub-alpine.*

Cardamine bellidifolia [Eu.]
Viola palustris [Eu.]
Silene acaulis [Eu.]
*Arenaria Grœnlandica.
Dryas integrifolia [Eu.]
*Geum radiatum; var. Peckii.
Sibbaldia procumbens [Eu.]
Potentilla frigida [Eu.]
Saxifraga rivularis [Eu.]
Epilobium alpinum; var. majus [Eu.]
*Solidago Virga-aurea; var. alpina [Eu.]
Gnaphalium supinum [Eu.]
*Arnica mollis.
Nabalus nanus.
N. Boottii.
*Vaccinium uliginosum [Eu.]
V. cæspitosum.
Arctostaphylos alpina [Eu.]
Cassiope hypnoides [Eu.]
Phyllodoce taxifolia [Eu.]
Rhododendron Lapponicum [Eu.]
Loiseleuria procumbens [Eu.]
Veronica alpina [Eu.]
Castilleia pallida [Eu.]

*Euphrasia officinalis [Eu.]
Diapensia Lapponica [Eu.]
*Polygonum viviparum [Eu.]
Oxyria digyna [Eu.]
*Empetrum nigrum [Eu.]
Betula glandulosa=B. nana probably of
Salix chlorophylla. [Eu.]
S. Cutleri.
S. argyrocarpa.
S. herbacea [Eu.]
Luzula arcuata [Eu.]
L. spicata [Eu.]
Juncus trifidus [Eu.]
*Scirpus cœspitosus [Eu.]
*Carex scirpoidea [Eu.]
C. capitata [Eu.]
C. rigida; var. Bigelovii [Eu.]
C. atrata [Eu.]
*C. capillaris [Eu.]
Phleum alpinum [Eu.]
Agrostis scabra; var. alpina.
Calamagrostis Pickeringii.
C. Langsdorffii.
Poa laxa [Eu.]
Festuca ovina; var. vivipara [Eu.]
Triticum violaceum [Eu.]
Aira atropurpurea [Eu.]
Hierochloa alpina [Eu.]
Lycopodium selago [Eu.]
L. annotinum; var. pungens [Eu.]

CANADIAN PLANTS NATURALIZED ON MT. WASHINGTON.

The species marked with the letter *M* in the catalogue are only those which are indigenous to the alpine and sub-alpine regions. Quite a number of plants, chiefly those of the Canadian region, have spread themselves upwards in favorable seasons, and are naturalized there to a certain extent. We present a list of those that have been gathered upon Mt. Washington, mostly in the sub-alpine district. They are also marked with the letter M not italicised upon the catalogue. Future explorations will add many to the list.

Ranunculus abortivus.
Thalictrum dioicum.
Viola canina.
Stellaria borealis.
Paronychia argyrocoma.
Rubus Chamæmorus.
Potentilla tridentata.
Spiræa salicifolia.
Ribes prostratum.
Heracleum lanatum.
Cornus Canadensis.
Linnæa borealis.
Lonicera cærulea.
Viburnum pauciflorum.
Houstonia cærulea.
Aster Radula.
A. acuminatus.
A. nemoralis.
Solidago thyrsoidea; var. alpina.
Taraxacum Dens-leonis.
Antennaria margaritacea.
Campanula rotundifolia.
Vaccinium Oxycoccus.
V. Vitis-Idæa.
V. Pennsylvanicum.
Chiogenes hispidula.
Kalmia glauca.
Ledum latifolium.

Trientalis Americana.
Rhinanthus Crista-galli.
Melampyrum Americanum.
Rumex Acetosella.
Betula papyracea; var. minor.
Alnus viridis.
Abies balsamea; var. nana.
Veratrum viride.
Clintonia borealis.
Streptopus roseus.
S. amplexifolius.
Listera cordata.
Habenaria dilatata.
H. obtusata.
Luzula parviflora; var. melanocarpa.
Juncus filiformis.
Eriophorum vaginatum.
Carex canescens; var. vitilis.
C. rostrata.
C. arctata.
C. trisperma.
C. limosa.
C. irrigua.
Phleum pratense.
Agrostis scabra.
A. canina.
Aira flexuosa.
Avena striata.
Trisetum subspicata; var. molle.
Aspidium spinulosum.

REMARKS. A careful comparison of the names of plants assigned to the two alpine districts in the lists above with those in the catalogue (Chapter XIII), shows that they do not harmonize perfectly. Different observers, without an opportunity for comparing notes and specimens, cannot be expected to agree in every minute particular; and Dr. Barrows and Mr. Flint have had no opportunity for interchanging their views. Each one mentions two or three species not given by the other. They do not enter upon the question of separating the alpine from the sub-alpine species. I commenced an investigation, hoping to be able to find distinctions in the distribution of these plants which might correspond with those among the insects mentioned by Mr. Scudder (p. 336), but have been doomed to disappointment. Prof. Gray's opinions, as held in 1856, are indicated, but these do not agree with those proposed by other eminent botanists with whom I have been in correspondence. These two districts are so near each other, and so limited in extent, that the climatic conditions are very nearly the same. Hence the species may have emigrated from their original limits, both upwards and downwards, so that the boundary line cannot be drawn. Another cause of intermingling may have been the climatic fluctuation intimated by the former occupation of the Canadian region by the Alleghanian forms up to the base of the mountains (p. 543).

As the evidence from the plants themselves is obscure, I think we may be warranted, in the further study of this subject, to assume as correct the insectean bounds given on Plate C, Chapter XII. Then notes should be taken of the distribution of all the plants above the line of trees. Should the facts thus gained not arrange themselves satisfactorily, the only other course is to study the distribution of the same species about Hudson's bay, Greenland, and other alpine districts, ascertain the denizens of the two zones in typical localities, and then assign to each group those of the White Mountain plants that are represented farther north. When we find fifty-eight species of Cana-

dian plants climbing into the alpine district, it is not strange that the smaller number of boreal species should in like manner spread themselves even into Alleghanian townships.

THE BOUNDARY BETWEEN THE ALLEGHANIAN AND CANADIAN DISTRICTS.

In order to show the near correspondence of the dividing line between the Alleghanian and Canadian districts, according to the several methods of distinction that have been suggested, I annex a map showing the course of the following lines, first,—the broad band settled upon by Mr. Scudder as separating the insects of the two faunæ; second, the upper line of the white oak; third, the approximate contour line of six hundred feet elevation; fourth, the isothermal line of fifty degrees for April, May, and June. It will be seen, by referring to the map showing the distribution of forest trees, that the chestnut limit does not fall much behind that of the white oak, the whole area occupied by it being colored.

The upper limit of the white oak extends above the six-hundred-feet contour line as far as Plymouth, from the south line of the state; may agree with it for a few miles in the lake region, but extends farther north in the Pemigewasset and Saco valleys. In the lower part of Carroll county there is an area above six hundred feet. I do not think the facts are known with sufficient precision to state the presence or absence of the oak in this area. There are other limited areas of greater height not indicated, as the Gunstock region, where the oak certainly does not flourish. Along the Connecticut the limit of the oak reaches as far as the contour line; while in the south-west part of Cheshire county the reverse is true. Were it legitimate to strike an average in this case, it could truly be said that the two lines correspond very well. There may be special reasons in every case of variation for the spread of the tree beyond or within the limits of the contour, derived from the character of the soil or particular topographical features, which might be discovered upon investigation. Somewhat similar variations appear upon examining the isothermal line of fifty degrees for the three months of April, May, and June, proposed by Prof. Verrill as the limit between the Canadian and Alleghanian birds. This line runs up to Berlin on the Androscoggin, may touch Jackson and Bartlett on the Saco, curving round the southern White Mountains to pass up to Thornton and War-

BOUNDARIES
BETWEEN THE
CANADIAN & ALLEGHANIAN
DISTRICTS IN NEW HAMPSHIRE
As proposed by different Authors.
EXPLANATION.
Band separating Insect faunae.
Area occupied by White Oak.
Contour line of 600 feet elevation.
Isothermal line of 50° for April, May and June.

ren, and, probably, to connect with the line passing up from White River Junction to Northumberland. Returning southerly from the south line of Stratford, it curves up the Passumpsic south of the Concord (Vt.) hills an unknown distance. From thence it would naturally follow back the Connecticut, on the west side, to ascend the White River valley. I think it must reach Craftsbury, Vt., from the White river, rather than the Passumpsic valley, this being a point on the line specially mentoned by Prof. Verrill.

From the facts already presented, one would infer that the six-hundred-feet contour line and the upper limit of the white oak approach nearer to the limits of the insect faunas, as given by Mr. Scudder, than the isothermal of fifty degrees. Two considerations, however, are important in this connection:—First, the distribution of the insects, birds, and trees may not coincide perfectly with one another. There is no law of nature providing that these areas should coincide with mathematical exactness. Second, these different lines have been drawn only approximately. When the temperature, altitude, and exact limits of all the birds, insects, and trees shall have been studied with special reference to the determination of this point, a closer correspondence may be discovered. I have gone as far as possible without making special explorations, using only what has been picked up incidentally. It would be of much importance to the agricultural interests of the state if such investigations could be pursued farther, since the accurate determination of this line shows the proper limits of the cultivation of the grape, cranberry, and the choicer fruits. Their cultivation is not now carried so far north as nature allows.

Extent of Forest.

It is often important to know how extensive the wood-growth of a country is; and, in order to illustrate this subject as far as possible, I have appended a small colored map showing the areas occupied by trees at the present time in New Hampshire, and a short distance into the surrounding territory. It is supposed the whole of the state was originally covered by the forest. The white parts of the map show how much has been cleared, and in what neighborhoods settlements have sprung up. The first glance at the map shows where the woodman's

axe has not yet penetrated, save for the purpose of cutting lumber. This dense forest occupies most of Essex county, Vt., the adjacent townships of Quebec, and nearly twenty townships at the north-west angle of Maine. I have tried to represent all the forest in Maine to the north-west of a line from Conway to the south part of Weld.

Several points deserve mention:—First, I have separated by another color the tops of the mountains which are above trees. As some may object to the correctness of this representation, I will explain. The largest alpine area, or region above trees, is coincident with the summits of the Mt. Washington range. It is given on a larger scale in Chapter XII, Plate C. Of the other White Mountain areas, Mts. Lafayette, Profile, Moosilauke, and Twin are certainly devoid of trees upon their summits. Of the others, Mts. Willey, Crawford, Mote, Pequawket, Chocorua, Osceola, Black, and Carter, with others not represented, are bare now, but may have been covered by a stunted growth originally. Possibly the Pilot and Starr King mountains, with the Stratford peaks, may belong to the same category. Certainly, Kearsarge, Gunstock, Sunapee, and Monadnock must be placed among those which once supported a stunted growth. In the clearing of the country, many of these summits became involved in the merciless destruction of the trees, and nature has not been able to rehabilitate them.

Second, oftentimes the trees are retained because they grow upon mountains or high hills. Such is commonly the case all over the White Mountains, much of Coös and Essex (Vt.) counties, the quartzite range from Piermont to Claremont, Red hill, Ossipee, Green mountain in Effingham, the Gunstock region, Moose mountain district, between Carroll and Strafford counties, Saddleback in Northwood, McKoy's and Fort mountain in Epsom, range from New Ipswich to New Boston, Uncanoonucs, large areas along the Connecticut-Merrimack ridge, hills in the south-west part of Cheshire county, etc. Third, for a similar reason, one can pick out woodland areas upon the county maps from tracts of land not traversed by roads. Some of the county maps, as that of Cheshire, take pains to point out where forests are situated, by appropriate markings. Fourth, the forest trees are disappearing rapidly in some sections, and gaining in others. The presence of a new railroad is the sure precursor of the disappearance of the forest. I have noticed

this fact in a marked degree along the Manchester & Portsmouth Railroad, in Auburn, Candia, and Raymond. The prospective opening of the Portland & Ogdensburg Railroad will soon witness the stripping of the forests between Whitefield and Conway. In the older and higher towns, between the Connecticut and Merrimack rivers, the trees are gaining. Hundreds of farms, showing the names of their owners upon the maps of twelve to fifteen years' issue, exhibit a return to the primitive condition. The houses are deserted or pulled down, and the grass-land is full of shrubs. The roads, also, in many localities, have been abandoned, and more ought to be, since they need repair so badly.

Nature is taking the proper course with much of our territory. She points out more desirable localities to the tillers of the ground, and, when they remove, the trees spring up again. It appears, from observations upon the salutary influences of forests, that a certain part of every country must be kept in wood-growth, in order to preserve the balance of nature. It is supposed that forests exert an influence upon the amount of moisture precipitated; and it is certain that the removal of the trees causes greater freshets after rain-storms, because there is nothing to keep the water back. With abundant vegetation present, moisture is absorbed, kept back, and evaporation is retarded. In time, legislation will require the replanting of much of our woodland, unless the planting of shade-trees abundantly in the settled districts, and the emigration of much of the hill population, restore the balance of nature, without the necessity of intervention. Legislation may judiciously hasten the restoration of forests by encouraging the planting of shade-trees; and it should be a part of the duty of agricultural associations to offer premiums for the production of artificial forests. Experiments in forcing the growth of timber trees may also be encouraged.

On the map I have endeavored to show where the principal patches occur. We might estimate by percentages, calling the original universal growth 100, and the average approximation to it in a township by the estimated part of the natural abundance now existing. But I have thought it easier to show by colors essentially the position and relative dimensions of the present wood-growth, premising that the cleared portions are more likely to fall short of than to exceed the representation.

Some very valuable facts in reference to the extent of our forests are

given in the answers by well informed persons in most of our towns to questions put by James O. Adams, secretary of the Board of Agriculture. I have condensed these estimates from the original statements in the third annual report of the secretary, presented in 1873. The question was couched in the following language: "What proportion of the area of the town is covered with forests?" I will give the substance of the answers, by counties, as briefly as possible.

Rockingham County. Atkinson, one third the area covered with wood-growth; Auburn, sixty-five per cent.; Brentwood, less wood and pasturage than improved land; Chester, about half; Danville, about half, mostly young growth; Derry, one fifth; East Kingston, one tenth; Epping, twenty per cent.; Fremont, forty per cent.; Hampton Falls, one fifth; Kensington, one eighth; Kingston, one fourth; Newmarket, one eighth; Newton, one half; North Hampton, one third; Rye, considerable area covered with bushes; Sandown, one half; Seabrook, one fourth; South Hampton, one twelfth; Stratham, less than half; Windham, more than half.

Strafford County. Barrington, more than half; Durham, one third; Farmington, "stripped of its forests;" Lee, a small part; Madbury, one fourth; New Durham, more than half; Rochester, a small part; Rollinsford, one twentieth.

Belknap County. Alton, one third; Belmont, one twentieth; Center Harbor, one fourth to one third; Gilmanton, one fourth; Sanbornton, one tenth; Tilton, less than one fourth.

Carroll County. Albany, three fourths; Bartlett, two thirds; Eaton, one third; Effingham, one fourth, Freedom, one third; Madison, one half; Moultonborough, sixty per cent.; Ossipee, one third; Sandwich, one half; Tuftonborough, one third; Wakefield, one half; Wolfeborough, one third.

Merrimack County. Andover, nearly one fourth; Bow, nearly half; Bradford, one twentieth; Dunbarton, one fourth to one third; Franklin, one eighth; Henniker, twelve to thirteen per cent.; New London, one eighth; Northfield, little less than one fourth; Salisbury, more than half; Warner, one fourth; Webster, one fourth; Wilmot, one fourth.

Hillsborough County. Antrim, one fourth; Bedford, one fourth; Bennington, one fourth; Brookline, one half; Deering, one tenth; Francestown, one third to one half; Goffstown, about one third; Greenfield, one fourth; Hollis, one fourth; Hudson, fifty per cent.; Lyndeborough, one fourth to one third; Manchester, nearly one third wood or hoop-poles; Merrimack, one half; Mont Vernon, one fourth; New Boston, one eighth; New Ipswich, twenty-five per cent.; Peterborough, one fifth; Temple and Windsor, each one fifth; Wilton one twentieth.

Cheshire County. Dublin, one twelfth; Fitzwilliam, one half; Gilsum, one fourth to one third; Harrisville, Marlborough, Rindge, Sullivan, and Walpole, each one fourth; Nelson, one sixth; Richmond, one tenth to one eighth; Surry, one third; Swanzey,

one third; Troy, one sixth; Westmoreland, one third; Winchester, two fifths to one half.

Sullivan County. Acworth, one third; Charlestown, one third; Claremont, one eighth to one fifth; Cornish, one sixth; Goshen, one third; Grantham, one half; Langdon, five per cent.; Lempster, one third; Sunapee, one sixth; Unity, one eighth; Washington, one third.

Grafton County. Ashland, nearly two thirds; Benton, three fourths; Bethlehem, two thirds (not including the recent additions); Bridgewater, one fourth; Bristol, one third; Campton, one half; Enfield, one third to one half; Hanover, one sixth; Hebron, one half; Holderness, one third; Lebanon, one eighth to one sixth; Lincoln, nine tenths; Lisbon, one half; Littleton, one third; Lyman, one third, Monroe, one third; Orange, one half; Piermont, one third; Plymouth, one third; Warren, one half; Wentworth, one half.

Coös County. Columbia, two thirds; Dalton, more than half; Jefferson, more than half; Pittsburg, seven eighths; Randolph, seven eighths; Shelburne, nearly three fourths; Whitefield, one half.

Size of Forest Trees.

The woodmen are so ready to cut down the largest trees in the forest, that it seems proper to preserve in permanent form a few facts that have fallen under our notice respecting the size of the larger specimens, of which there is an authentic record.

David M'Clure and Elijah Parish, in their memoirs of President Eleazer Wheelock, of Dartmouth college, state that it was common a hundred years since to see pine trees in Hanover over 200 feet in length. One of them measured a pine growing within the academic precincts, and found it to be 270 feet long. Some of the present officers of the college thought these dimensions rather large; but the late President Lord came across the ruins of an old pine in one of his rambles, and, by pacing, proved the length of it to be 230 feet.

Dr. Williams, of Vermont, states the height of the pine to be 247 feet. Zadock Thompson has seen them 170 feet long, and measuring about 6 feet on the stump. He also says the larch attains the height of 100 feet, with a diameter of about 2 feet.

The following notices of large trees I have obtained from items in the *Independent Statesman*, during the past four years, and presume the figures are essentially correct.

Granville Felton cut, on the farm of D. W. Trow in Amherst, a chestnut tree which measured 7 feet in diameter at the butt.

William Patterson obtained a chestnut log in South Merrimack, 54 feet long, 17 inches through at the top, 5 feet 8 inches at the butt, containing 174 feet of lumber, board measure.

Schuyler Aldrich, of Great Falls, cut an elm tree measuring 4 feet 8 inches in diameter at the butt, and 3 feet 8 inches 40 feet higher up. At this point two limbs branched off, each 2 feet in diameter.

Near the Concord Railroad in Greenland, there stands an elm which measures 27 feet in circumference 6 feet above the ground.

James Thatcher, of Moultonborough, cut a hemlock belonging to George Thatcher, which measured 90 feet in length. It seemed to have 290 rings of growth.

Andrew Farnum, of West Concord, cut a red oak, being 5 feet in diameter at the butt, the log weighing over 3 tons.

S. W. Vose, of Peterborough, cut a maple 3 feet in diameter, with 370 rings of growth.

W. S. Marston, of East Andover, cut 4⅝ cords of wood from a pasture maple.

The Messrs. McIntire, of Littleton, recently cut a spruce tree on Palmer brook, measuring 130 feet in height, and 16 inches in diameter 65 feet from the ground.

Amon Lord, locality not stated, cut a pine 5 feet in diameter at the butt; 32 feet higher it was 4½ feet through. The entire tree furnished over 4000 feet of lumber.

W. K. Quimby has a pine measuring 21 feet in circumference at the base. It is as straight as a candle, and limbless for 100 feet above the ground. It is estimated to contain 7000 feet of sound lumber.

Two pines on land of John Batchelder, of Laconia, scaled 3500 and 3000 feet respectively. One was 140 feet long.

W. H. F. Staples, of Errol, hauled in a spruce log 64 feet long, measuring 1130 feet. Mr. Marden cut a pine on the College grant, measuring 54 inches in diameter on the stump. The butt log, 28 feet long, scaled 5000 feet.

Mayland & Woodman cut a pine on the Atkinson Academy grant, which scaled 12,000 feet. It was 7 feet 4 inches in diameter on the stump, and 3 feet 1 inch in diameter 90 feet from the butt.

Charles Gray cut on the Parker lot, North Charlestown, a pine whose stump measured 5 feet in diameter. The logs amounted to 115 feet in length. It was 2½ feet in diameter 44 feet from the ground. There were four of about the same size.

There are five enormous elms in front of the residence of Jos. B. Walker, Concord,—transplanted to their present positions 110 years since,—measuring, at the height of 3 feet from the ground, in 1871, from 9 feet 4 inches to 16 feet 10 inches in circumference. In fifteen years the largest one increased 10 inches in girth. Two others, during the same time, increased from 16 to 19 inches.

In Dr. Bouton's *History of Concord*, it is stated that Lieut. John Walker cut a pine in Northfield measuring 38 inches in diameter 60 feet from the butt.

The Destruction and Renovation of the Forests.

BY J. H. HUNTINGTON.

At the time of the advent of the white men, the whole state, except perhaps some small areas on the rich alluviums where the Indians raised their corn, was covered with a dense forest from the sea-shore almost to the summits of the highest mountains. Along the streams especially the pines assumed gigantic proportions; but now those suitable for masts are found only in the deep ravines far up among the recesses of the mountains. In general, the deciduous trees were found on the fertile uplands, while the swamps, the ravines, and less fertile uplands were occupied by coniferous trees,—the spruce, the fir, the cedar, and the larch. Where there was nothing except boulders, a thin bed of vegetable mould formed from the decay of moss supported only a growth of fir.

The destruction of the forests by the axe and by fire is becoming a matter of serious consideration. In clearing land for cultivation, the trees when cut down are almost invariably burned, and, that this may be effected as completely as possible, the driest weather is frequently selected, although the fire is much more likely to spread into the surrounding woods. It is a common notion, with those that clear land, that if they get a "deep burn" they will secure better crops. It is very true that better crops may be obtained for one or two years, but after that, if all the vegetable matter was burned, the land will be almost worthless unless the vegetable matter is restored. Much of the sterility of our soil is undoubtedly due to this cause. In our forests large quantities of dry branches and tops of trees are left by lumbermen, and these, when dry, are exceedingly imflammable. Although the primitive forests, except near the summits of the mountains, are rarely subject to conflagrations, yet, whenever an opening is made through which the sunlight is admitted, the mossy soil, on which the propagation of fires largely depends, readily takes fire. In fact, the fires are sometimes confined to this alone, and, during a whole summer, the fire may not extend over more than an acre of ground. In such cases it burns up entirely the vegetable mould from which the forest trees spring. Here and there a tree falls; but, in the

first gale of autumn, the trees on the whole burnt area are prostrated, and generally in the greatest confusion, for every tree is torn up by the roots, and seems just as likely to fall one way as another. There was an instance of this kind of burning in the summer of 1871, about two miles north of the Glen house, between the river and the road; also, the same season, on the mountain south of West Milan, and the fire was not put out until after the snow came. On the summits of the mountains, where there is nothing scarcely except lichens and sedges, if a fire is kindled in these when they are dry, which is a thing quite uncommon, it sweeps across the mountains with incredible rapidity; and the roaring of the flames can be heard for miles, when they reach the stunted growth of the spruce and the fir. On a mountain of moderate elevation in North Stratford, it is said that the lightning set the woods on fire; but such cases must be extremely rare. When the fire, instead of being confined

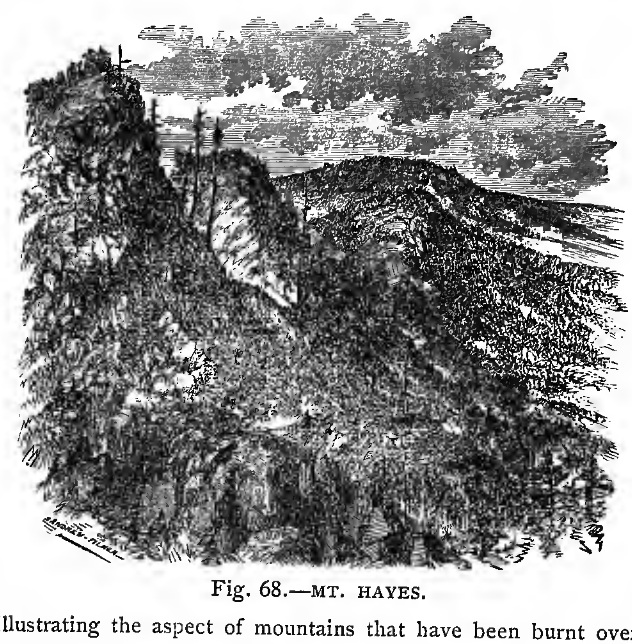


Fig. 68.—MT. HAYES.

Illustrating the aspect of mountains that have been burnt over.

to the ground, runs up the white birch, the bark of which is so inflammable, it catches in the branches of the coniferous trees, and streams far above their summits in columns and streamers of lurid flame; the wind carries pieces of lighted wood across the widest streams; and the

progress of the flames continues sometimes until hundreds of square acres are devastated.

When the fire has run through a forest, if it is a hard-wood growth, there are often some trees that escape its ravages; but the paper birch very rarely survives a forest fire. Persons, travelling through our primitive forests, frequently set the bark of the birch on fire to see it burn; and fire from these is communicated to other trees, and large areas of forest are consumed. When the woods consist of dark growth or coniferous trees, the fire not only kills the trees, which are left to furnish fuel for a second conflagration, but it is also communicated to the ground, and a large part of the vegetable substance of the soil is consumed. The trees fall with the first wind, and the fire of another year leaves not a trace of vegetable matter on or in the soil. Mote mountain is a notable instance of this, for here, over large areas, there is not a vestige of any thing vegetable.

It would be interesting to trace the way in which the restoration of our forests is effected, but we can only indicate some of the methods. In our northern forests, if only those trees are removed that are useful for lumber, and the land is not burned, the same description of wood is immediately reproduced. In most of our primitive forests there are very many young trees, from mere saplings to those almost ready for the axe of the lumberman. These now having the sunlight, with those produced from seed, soon take the place of those removed. In the southern part of the state the stumps of the deciduous trees produce shoots, and soon, over the whole area where the trees have been removed, there is a vigorous growth from this source alone. In the northern part of the state this mode of reproduction is exceedingly rare. In most cases, if the entire growth, including the underbrush, is removed, a different growth from that which occupied the soil will succeed;—along the northern boundary we have an illustration of this. Where the trees are burned, and only a part of the vegetable substance of the soil is consumed, the first year there is a luxurious growth of herbs. The *Epilobium*, known as the fire-weed, will probably be the first to take possession of the soil; and we shall be likely see species of the *Trillium*, the tubers of which, deep in the soil, have escaped the fire. The bunch-berry, *Cornus Canadensis*, and wintergreen, *Gaultheria*

procumbens, will very soon find places. Of shrubs, the cherry will be the first; but, in places where there is still some vegetable substance left, these will soon be succeeded by a growth of poplar and white birch. In more southern latitudes, the shrubs and trees that spring up in burnt districts are entirely different.

When the entire vegetable substance of the soil has been burned, the process by which the woods are reproduced is long and complicated. Lichens and mosses then first cover the ground, and, by slow degrees, flowering plants appear. Among the first shrubs, especially on mountains and on sandy plains, there will be some species of the blueberries. On Percy peaks, where years ago everything except the rocks was consumed by fire, the vegetation can now be seen to increase year by year from the base upward. A few examples will show the contrast which appears between the primeval forest and that which succeeds it. If we ascend Mt. Washington by the railway, when we are above the limit of the trees, if we look westward, we shall see that in the valley of the Ammonoosuc there is a growth of deciduous trees that extends on either side far up the side of the mountain ranges that border the valley. Some forty years ago a destructive fire destroyed the primeval forest of spruce and fir; and now in all this tract the principal growth is the paper birch. Besides this, however, there is the yellow birch, and now and then a poplar; and, as a new growth, we find the original occupants of the soil. In some parts of the town of Success, the only growth now is poplar; and elsewhere there are places where there have been so many successive fires, that blueberries, mosses, and lichens are the only growth.

The bare ridges and mountains west of the Saco show that the vegetable matter in the soil even has been consumed, so that it must be many years, even if there are no fires, before enough will accumulate, from the decay of lichens and mosses, for any vegetation whatever to grow, except the very lowest forms. On the line of the boundary between New Hampshire and Quebec province, where in 1845 the trees were cut, making an opening in the forest four rods wide along the entire northern boundary of the state, in general, where there was a hardwood growth, it was soon reproduced, but, in places particularly where there was a growth of coniferous trees, the cherry at first predominated;

elsewhere the swamp or mountain maple formed such a thick growth as to crowd out everything else for a time; but now both these are being replaced by the fir and the spruce.

It might seem a very small thing at first that the mountain tops should be bared, the slight growth of vegetation and the peat being consumed by fire; but this peaty soil holds great quantities of moisture deposited from the passing clouds, and of rain that often in summer is poured down in such floods as to cause terrible havoc along the mountain streams. It does not require much foresight to see that, if half of this water is retained on the mountain summits instead of being poured at once into the ravines, not only the freshets would be moderated, but that the water retained would be evaporated from the place where it fell, instead of being carried by the rivers into the sea; and thus there would be a more equal distribution of rain in the vicinity of the mountains, and we should not see in the valleys the dry and parched vegetation which is not only ruinous to the farming interests, but also destroys the natural beauty of the scenery.

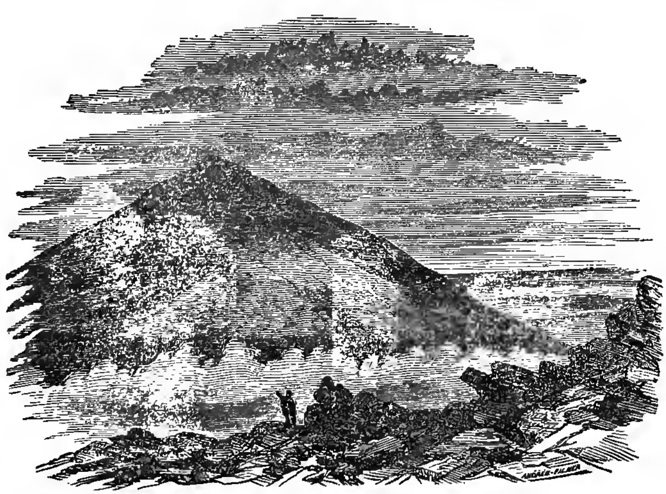


Fig. 69.—MT. MADISON, AS SEEN OVER ADAMS RAVINE.

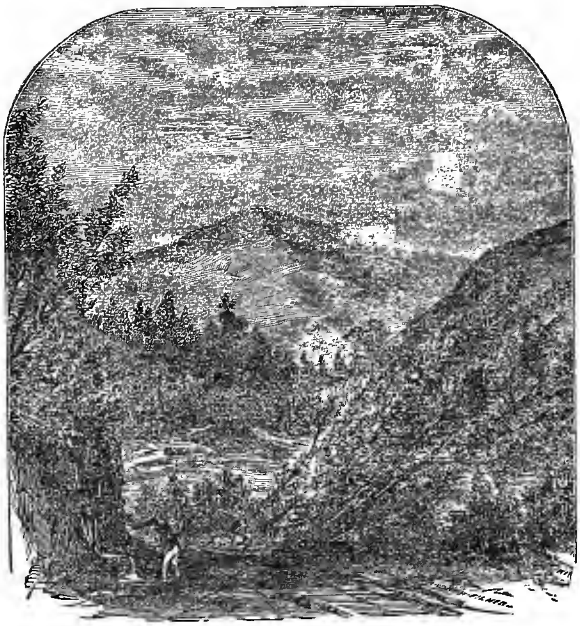


Fig. 70.—PEABODY RIVER AND MT. WASHINGTON.

CHAPTER XVIII.

SCENOGRAPHICAL GEOLOGY.

THE thousands of people who visit the White Mountains in the summer are attracted ostensibly by the scenery. They climb Mt. Washington that they may view the widest-spread landscape visible from any summit in America east of the Rocky Mountains and north of Mt. Mitchell. The interest attaching to the crystal cascades and the picturesque Winnipiseogee is produced by a different element, though less fascinating to most. From North Conway, multitudes watch the gorgeous colors among the shifting clouds, when the sun is setting. There are also other features that render the Alps of America attractive to the summer resident.

Considered more particularly, the following are the principal elements which enter into landscapes: first, mountains, hills, valleys, and all configurations of the surface; second, ledges; third, water, whether quiet or

in motion; fourth, forests and vegetation in all stages of being, whether the trees clothed in verdure, or painted brilliantly as the leaf is about to die, or the diversely colored vegetation of swamps and alpine regions; fifth, the effect of the sky, whether clear, or variously decked with clouds; sixth, the position of the sun and moon, perhaps producing shadows or showy prisms of color to brighten the scene. To consider all these elements would be inappropriate for this volume; and I shall chiefly confine myself to the first one mentioned, and point out several of the ways by which the shapes of our mountains and hills have been modified by geological agencies. I have given a large number of views of landscapes in the volume, and will describe such as are specially pertinent. At the end of the chapter is appended a list of the sketches given in this report, which illustrate the various phases of the subject. Descriptions of the charms of sunset, cloud effects, light and shade, the myriad tints of vegetation, the varied colors of the hills, and the brilliant hues of autumn, need not be looked for. Fortunately, those who desire to read such sketches will find in Starr King's *White Hills* ample treasures of this kind of word-painting.

The only other important work upon the scenery of the White Mountains was prepared by William Oakes, of Ipswich, Mass., in 1848, with sixteen folio lithographs, after drawings by Isaac Sprague. Only a few copies were published, and very few persons have seen the book. Mr. Oakes was an eminent botanist, and enthusiastically interested in everything pertaining to the White Mountains. Except for the accident which closed his career, he would have done much more for our scenery. First, are four pages of text devoted to a general notice of the scenery; and then each plate has about a page of explanation inserted before it. Later writers have drawn freely upon Oakes's material. There are heliotypes in this report corresponding to nearly every one of these drawings of Mr. Sprague. They miss, however, the unusually careful copying of the trees and plants in which Oakes was so well versed. Many of our alpine plants were first discovered, and now bear the scientific names imposed by him.

The following are the subjects of Oakes's volume:

Plate 1. The White Mountains, from the Giant's grave, in front of the present Fabyan house. Essentially this view appears in Fig. 25, and in the heliotype taken from the Fabyan turnpike. The ravines on Mt. Pleasant and towards Washington are delineated with great truthfulness.

Plate 2. Mt. Crawford, with the Mt. Crawford house, kept by Abel Crawford, in the foreground. This is the same with our view having Dr. Bemis's new residence in the foreground.

Plate 3. Notch of the White Mountains, with the Willey house, taken from the famous slide. This is the same with our small heliotype of Mt. Willard.

Plate 4. Silver cascade. This accompanies the previous heliotype.

Plate 5. Gate of the Notch, with the Notch house. This is reproduced in our view from the Crawford house, save that no vestige of the Notch house is now left. It was situated at the base of the Elephant's Head.

Plate. 6. Lower falls of the Ammonoosuc. Preserved only as a small relief-plate illustration in the next volume.

Plate 7. Two enlarged views of the cliffs at the same locality. The building of a saw-mill, the construction of a heavy railroad embankment alongside, and the removal of the forests have taken away all the romance pertaining to these falls in Mr. Oakes's day.

Plate 8. Franconia notch, taken from the west. We have a small heliotype of the same cliffs from the south, which seems to us to reproduce the spirit of the mountains better than this plate.

Plate 9. Profile mountain. Nothing equal to this appears in the report.

Plate 10. The Profile rock. Reproduced in Figs. 74 and 75.

Plate 11. The Basin. Reproduced in a heliotype.

Plate 12. The Flume. We have a view in the next volume of the great boulder suspended over the Flume. This lithograph represents the whole of the gorge, also.

Plate 13. Nancy's bridge.

Plate 14. Mt. Crawford, from the Notch, and view in the opposite direction from the top of Mt. Crawford. The reproduction of the first appears correctly in Fig. 26 and in a heliotype. But the artists have exaggerated the shape of the top of this mountain, as will be seen by comparing Fig. 26 with our heliotype, which was taken from almost the same spot.

Plate 15. White Mountains, from Bethlehem; Mt. Washington, from the summit of Mt. Pleasant; diagram of the whole range of the White Mountains. Only the second of these is reproduced.

Plate 16. Mt. Washington, from over Tuckerman's ravine. This is essentially the same with our view of Mt. Washington from the south-east, and reveals features in the structure of the range not so apparent from any other quarter.

I may reasonably take the ground that every interesting feature of New Hampshire scenery has been produced by geological agencies. In proof of this proposition I would refer to the fact of the existence of mountains, hills, and valleys. Not one of these ever came up out of the depths without the aid of that force called elevation. Next, the present shape of every ledge or mound has been fashioned by some excavating agent,—rill, river, glacier, ocean wave, or atmospheric decomposition. Lakes exist because permitted by the rock-bound barrier, or looser earth,

liable to give way, and precipitate calamity upon the valleys beneath. Rivers plunge down precipices, giving rise to cataracts and cascades. Vegetation assumes character according to the degree of elevation. Even the pure skies, the gathering of mists and clouds, depend upon the presence of the elevated ridges. Hence I think the position well established that geological agencies have produced all the charms of landscape; and, were we so disposed, we should be amply justified in describing minutely the special causes of change that have fashioned every foot of surface. Those who would thoroughly understand the features of our scenery are invited to peruse the various geological details of this report. They will be necessary, and more besides, if one would describe our mountains with the pains which Ruskin takes to set forth the causes that have moulded the Alps into their present form. Many may imagine it to be of little consequence whether Mt. Washington be an anticlinal or synclinal axis,—whether it be composed of granite or slates; but the decision of these scientific questions is essential to the proper delineation of its scenographical structure. The artist, who represents a mountain correctly upon canvas, has discovered the fundamental type of its structure, whether he uses geological phrases or not,—otherwise his painting will not be recognizable.

It is a well known fact that many surface configurations are due to a peculiarity of rock formation. Conical hills suggest a volcanic origin; and if on examination they prove to be composed of scoriæ or lava, the evidence is plain of igneous eruption. A prairie is not merely an expanse of thick loam and deep soil; it is underlaid by horizontal layers of rock, which give evenness to the surface as truly as to a table-land. Chalk hills, not common in the eastern half of our continent, assume rounded and graceful undulations in consequence of the easily-moulded character of the mass. Similar shapes characterize limestone hills. Ranges like that of Holyoke in Massachusetts and Connecticut, precipitous on one side and sloping on the other, assume this form in consequence of the situation of the hard trap-rock of the mountain. It dips easterly, so as to expose the tough edge of an inclined sheet high up in the air, and this covering protects the underlying friable material from denudation. The Table mountains of the Sierra Nevada slopes are the remnants of horizontal igneous overflows which have never been

tilted up by elevating agencies like the Holyoke mountains. The falling of Niagara river over a precipice has worn out a narrow gorge seven miles in length; and the cataract is receding every year, and will continue to move backwards till Lake Erie is reached. Elsewhere the softer rocks may determine the position of the eroding river.

I have mentioned these cases because they are familiar,—but take the ground that every one of our hills and valleys has been moulded into the particular shape for which its materials are fitted by the action of the sculpturing agents.

It is also true that rock-sculpture is largely dependent upon geographical position. The Egyptian traveller finds the chisel-work of fifty centuries ago as plain as that made a year since upon a New England sandstone. A dry climate is adapted to preserve, while one charged with moisture and cold rapidly disintegrates nearly every known substance. Hence the same rocks, which are interminably channelled on the eastern slopes of the Andes, are jagged and precipitous on the rainless western sides of the same range in Peru. No agent has been more effective than ice in subduing the rougher elements of scenery; and for this reason the sublime and awe-inspiring elements are largely wanting in our landscapes. The relentless glaciers have removed the pinnacles, smoothed the northern slopes, and toned down our valleys, allowing the picturesque feature to become predominant, and having regard, also, to the agricultural necessities of the land.

The understanding of the forces which have fashioned our topographical structure is complicated by the great length of time erosion has been going on, and the diverse character of the agents. If our territory constitutes some of the oldest dry land in the country, as is advocated in a previous chapter, not only the rains and snows of historic time, and the glaciers of the Drift period, but the rains, snows, and ocean waves of all geological time have been at work upon our rocks, and accomplished herculean tasks of excavating, grinding, and transporting. The result has been naturally the obscuration of shapes which certain summits would assume under normal circumstances. Furthermore, the precise amount of action in each period is only partially known. Hence a complete knowledge of the causes fashioning our landscapes is of difficult attainment, and its full enunciation tedious. We must be excused, there-

fore, for stating the causes and methods of sculpture in general terms only.

The special forms assumed by our mountains are mostly those peculiar to the crystalline schists, subsequently modified by glacial action. The most readily distinguishable are the following: First, conical mountains having some resemblance to volcanic summits, but composed of the earlier eruptive rocks, like granite, sienite, and protogene. Second, long reaches of rounded ranges composed of schistose formations. To this class most of our ridges belong. Third, isolated more or less conical masses of the same class of rocks. Fourth, deep, narrow valleys of erosion, akin to gorges and cañons. Fifth, broad, sloping valleys. Sixth, plains formed by transportation of drift. Seventh, terraced valleys. Eighth, limestone hummocks. Every one of these typical forms has been modified by the drift agency.

Agents of Erosion.

The agents of erosion should be briefly mentioned. They are mainly atmospheric disintegration, rain, rivers, glaciers, icebergs, ocean, land-slides, and the great northern Drift. Each of these agents has left behind its particular mark, by which the work performed may be easily identified. Some of them have operated with greater intensity in the by-gone periods of geological time than at present; others are supposed to have been more energetic in their action in the more recent epochs.

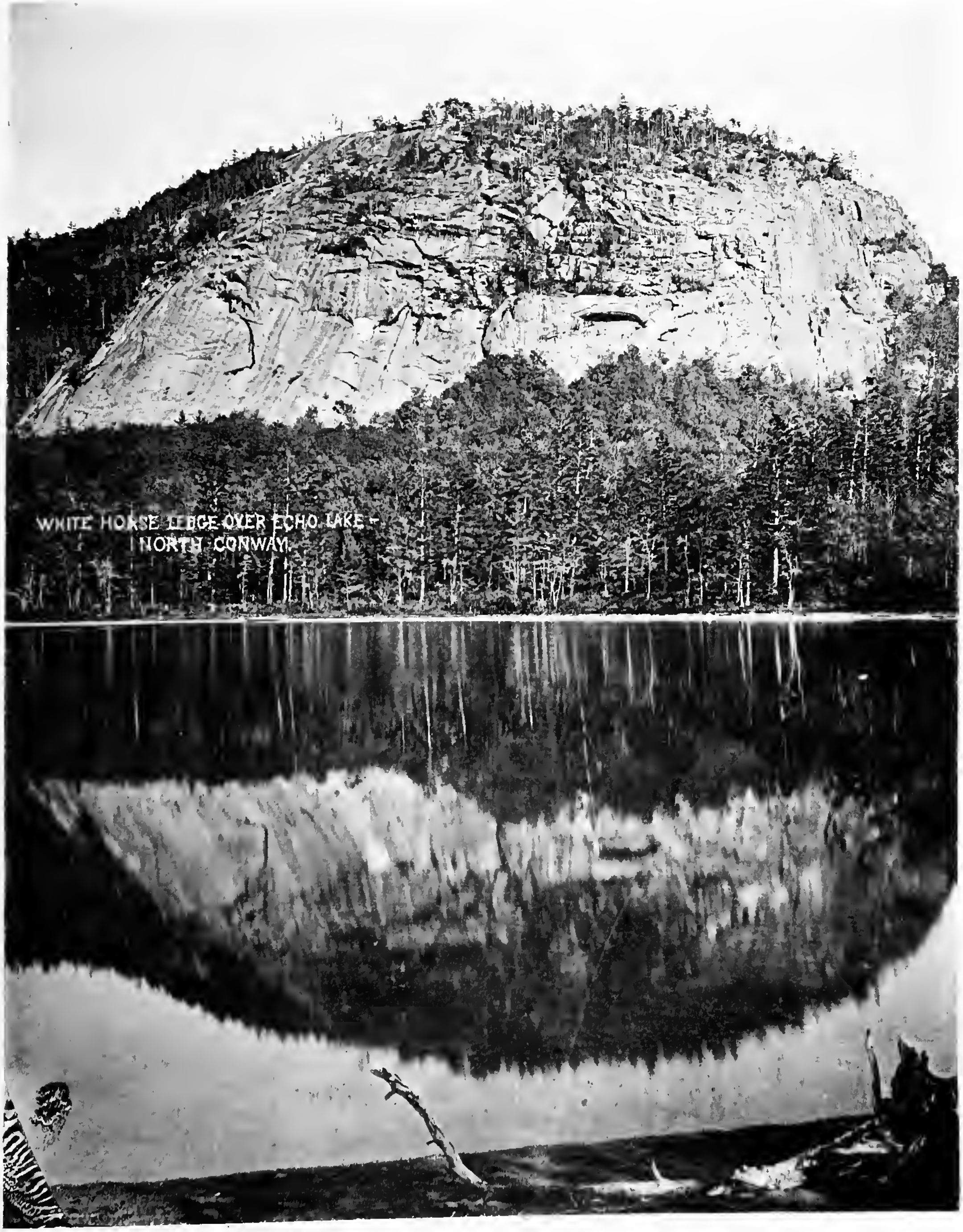
Atmospheric disintegration has been the most powerful of these agents acting throughout all the periods, yet it is of comparatively little consequence at the present day. I refer especially to the penetration of the ledges by carbonic acid, introduced partly through rain-water, and partly acting upon the surface by its envelopment of the ledges. Before the Carboniferous period, when a large share of the work of disintegration in New Hampshire had been accomplished, the atmosphere contained a much larger proportion of this reägent than it does now, and, of course, its action upon the surface must have been more manifest. I refer to the decomposition of feldspathic rocks more particularly,—a reaction that has been alluded to previously (p. 550),—resulting in beds of white kaoline clays and gravelly heaps for the residua, while the saleratus flows off in the streams. Consequently this decomposition is

remarkably clean. The clay is of a variety used for the manufacture of porcelain ware; and the sandy residuum in some cases is pure enough to be mistaken for loaf-sugar, as in Acworth. Furthermore, everything about the mountains of this character must be clean. The waters will be clear and sparkling; the earth will hardly soil the hands by handling it; the ledges, when uncovered, will appear blanched; the sand and gravelly bottoms of rivers and ponds will not be slimy and treacherous.

When the attempt is made to measure the amount of this species of denudation, the results are startling. Referring elsewhere for the details, it is sufficient to state that the pre-glacial erosions of our territory, due mainly to this cause, have removed from the present surface as much rock as now exists above the level of the sea. The average height of the land above the ocean in New Hampshire has been estimated at 1400 feet (p. 296). Our proposition maintains that the amount which has been removed from above the existing surface is equal to a blanket 1400 feet thick and 9392 square miles in extent.

The markings left behind by this kind of decomposition are less conspicuous than the others, and not so easily identified. Its tendency is to crumble down bluffs, blunt sharp angles, and to act simultaneously upon all sides. Should a stream of water be diverted upon certain ledges undergoing atmospheric disintegration, excavation will go on there more rapidly than elsewhere, since the recently separated grains of rock will be washed away, and expose fresh surfaces to chemical action. Such action would tend in time to produce pinnacles, such as those made known to the public in the Garden of the Gods, Colorado, and elsewhere among the Rocky Mountains, by means of photographs. When these pinnacles stand upon high table-lands, they will bear relationship to the Needles or *Aiguilles* of the Alps, referred by Mr. Ruskin to glacial action for their formation. In this case the ice has continued the wearing action commenced by the rivulets.

The action of streams of water may next command attention. Here the fact of geographical position must be taken into account. Two types of valleys result from this cause. In the rainless districts of the southwest part of our country, long ravines called cañons are abundant. Plateaus, hundreds of thousands of square miles in extent, are traversed by narrow chasms cut down perpendicularly by rivers and their tribu-


WHITE HORSE LEDGE OVER ECHO LAKE —
NORTH CONWAY.

taries. These narrow gorges may be continuous for hundreds of miles. The surface of the country is dry, parched, mostly without vegetation, both for the want of rain and the settling down of all the water flowing through the country from the moist regions higher up to the bottoms of the cañons, hundreds and sometimes thousands of feet below the general level. The edges of the ravines are sharp, as no tributary rills wash away the projecting angles. This type of river erosion is represented in the well-watered districts by short gorges, where rivers fall over precipices, and gradually eat their way up the channels. But the edges of the gorges below the cataracts are being gradually rounded, and pass insensibly into the other type of river-sculpture.

The other type is best expressed by the general term of *valley*. The constant flowing of small streams down the banks of rivers removes the angles of the square edges of the plateau, and there result gradual slopes from the water's edge to the dividing ridge between different hydrographic basins. The valleys are broad or narrow in proportion to the amount of rain flowing down the banks, not forgetting that the original direction may have been given to the water by the formation of synclinal basins.

These two types of river action are very marked; and the geologist, by this feature, can at first glance determine whether a newly-visited country is a dry or rainless one, and, to some extent, whether the rains are abundant or limited.

On applying these criteria to New Hampshire, we find many examples of interest. One immediately recalls the flumes at Dixville, Lincoln, and Nancy's bridge, as similar to the cañons. These, however, owe their perpendicularity to the nature of the rocks. Along the river-beds are easily decomposing dikes, which are quickly worn away by the water. Then the granite bordering the dikes is permeated by joints parallel to the stream. The action of water freezing in the seams has pushed out the first layer of rock on each side, and thus the flumes are quite wide, with vertical walls.

Limited gorges are quite numerous. They are to be explained either by the presence of softer rocks in the beds of the streams, or by the falling of water over precipices. Many of them will be noticed hereafter.

There is a gradation from the narrow valleys, where water runs more

swiftly to the broader and gently descending expanses. Cases of the former kind are in Wilton, Lyndeborough, and Mont Vernon. The Souhegan and its tributaries have cut channels two or three hundred feet deep out of a plateau. The most of the farms are upon the high ground. Every river valley in the state illustrates the type of river erosion peculiar to the rainy districts, or the broader instances just referred to, and it is not needful to specify examples. I do not know that the erosion has been more thorough in those districts said to receive the greatest annual fall of rain.

The action of glaciers like those in Switzerland has not been of great importance in shaping our valleys, since so much more important results have been produced by the "Drift." The local glaciers scoop out valleys; they leave behind moraines, either irregular mounds or small ridges athwart the streams, since cut through. Frequently the sides of the valleys have been left vertical, with ice-markings upon the walls. These mural surfaces are never extensive.

Ocean action is peculiar. Rocks exposed to the waves usually present a precipitous front, since the wearing away takes place only at the base of the cliff. When the ledge or bank of earth has been undermined, the top falls off, and thus a precipitous front is always exposed ocean-wards. In studying the landscape back from the shore, these precipitous cliffs may be seen where there has been a submergence in recent times, their bases all occupying the same level. Ancient sea-beaches usually accompany the former shore-line thus indicated.

The most important sculptor has been the ice of the Drift period. Thousands of facts will describe minutely all the phenomena of this sort hereafter; but the style of markings left by them may be readily recognized everywhere. I have for good reasons made a broad distinction between the Drift and local glaciers, the latter having exerted very feeble influences as compared with the former. Every mountain and rocky hill in the state, except the upper five-hundred feet of the Mt. Washington cone, show the markings of this mighty rock-breaker; and therefore its influence has been more potent in giving the present shapes to our scenery than that of all the other agents combined.

The distinguishing mark of ice-action in the Drift period is the rounding and smoothing of the ledges. Invariably our rocks have been rounded

by a force proceeding southerly. Whether you examine the bosses of rock in the Connecticut valley, the Mt. Washington ridge, or the islands of Winnipiseogee, every one that has not been shattered by the frost of more modern winters shows a distinct smoothing and rounding upon the north side, while upon the south the original roughness is preserved. The terms *stoss*, or struck, and *lee* have been applied to these two varieties of appearance. Their origin is obvious. The immense ice sheet in pushing southerly strikes every ledge with prodigious energy; and the flinty fragments frozen into the congealed mass will break off all rock projections in the way, and smooth over that which is too solid to be broken. And this force will be exerted entirely upon the sides that receive the blows,—consequently the lee surfaces will be rough and jagged. This action shows why we have no pinnacles of rock, such as abound in the Alps. The Swiss glaciers have plowed around these pinnacles, and left them standing; but the American continental Drift was of such vast proportions that the needles disappeared as though they were pebbles in the path of the ordinary river of ice. This statement is intended to apply only to North America east of the Missouri and north of the Ohio rivers.

For examples of this action on a small scale, let every New Hampshire reader search out the nearest freshly uncovered ledge to his residence, and the markings will show themselves to his view, for they are everywhere. Then observe the shapes of mountains. Look at the profile of Mt. Kearsarge, as seen from the east or west sides. There is a grand, smooth, unbroken slope from the valley of the Blackwater to the very summit, including a small foot-hill; while upon the south you observe irregular hills, the "Mission ridge," "Plumbago point," and other irregularities, where the ice passed over lightly without scraping off everything down to the base. Monadnock shows the rounding very prominently upon the northern slopes, but near inspection is requisite to reveal the jaggedness on the south. Figs. 63 and 64, on pages 540 and 541, show the stoss and lee sides, though the smallness of the scale of illustration impairs the clearness of representation. The backs of Mts. Jefferson and Adams have been smoothed over, their ledges, when stripped of moss and trees, revealing the striations and polishing, while in the picture only a general rounding is apparent. In the other sketch, the

precipitous southern slopes of the same mountains illustrate their primitive character. Another sketch, showing the abruptness of the lee sides of mountains, appears on page 12. Fig. 22, of Mt. Carter from Gorham, may also illustrate the long slope on the north smoothed by the ice-graver, while the south side is precipitous. The mass simply fell over it, without making any impression.

The nearest approach to a pinnacle in New Hampshire is Mt. Chocorua, shown in Figs. 31 and 61. But the back side of this sharp summit is marked quite abundantly by the peculiar striations left by the Drift. Hence, though one needs to stand on the summit to perceive the difference between the stoss and lee sides, it is evident a long spire was broken off when the ice went over Mt. Chocorua.

A still more common ice-mark than the sculpturing of the ledges is seen in the formation of the piles of rubbish transported from their original locations in the solid ledges, and strewn broadcast over the hills and plains. The local glaciers often transport blocks of stone upon their backs; and in like manner our Drift has carried boulders scores and hundreds of miles. But there is reason to believe that the principal portion of the earth-mass known as *hardpan*, and the majority of the accumulations seen in our walks, have been pushed along under the ice. Consequently the arrangement of the rubbish is less orderly than in the moraines of the smaller glaciers. The earth and stones have been dumped over precipices, filled up holes, levelled over irregular surfaces into plains, etc. This action has been very beneficial in preparing the country to support forests and most agricultural products. But besides the deposition of the hardpan, the materials have also been left in innumerable localities in the form of conical and ridged hills, straight, tortuous, and irregular. Large boulders abound in many districts, often so numerously as to render the smoothing of extensive fields by their removal practically impossible. From a scenographic point of view, these boulders are often attractive, as, for examples, the boulders in Bartlett and Conway, shown by heliotypes in the next volume, Vessel rock in Gilsum, Ordination rock in Tamworth, and others. A good example of a number of blocks is the stereograph entitled "New Hampshire Cow-Pasture," in Stratford.

The surfaces smoothed by ice are readily distinguished from those


CARRIGAIN NOTCH.

polished by water-action. The former usually exhibit striations parallel with one another, and which also show the direction taken by the current. The ledge covered by them may feel rough to the hand, but to the eye appears rounded in a general way. The latter are smooth to the touch, unless the rock is very coarse in texture; but there is not the general rounding of the mass, as seen in the other type of sculpture. The surface may be covered by a multitude of minor irregularities. This type of smoothness is best seen on boulders and ledges along the beds of mountain torrents.

The action of frost greatly assists in the work of disintegrating ledges. In the colder months water penetrates the crevices of ledges, and then freezes. As water expands in freezing, the effect is seen in the breaking off of larger or smaller fragments of rock from the ledge. Certain situations are especially favorable for this type of action. One is upon the summits of the higher mountains. The finest known example is upon the summit of Mt. Washington, and, to illustrate it, a heliotype has been taken. By referring to it, the reader will observe large, angular masses of rock scattered about promiscuously, just as they fell off from still larger masses. Some of these are permeated by cracks, which will by and by enlarge, and again fracture the rock in the same way that has been described. The process of freezing and crumbling will go on so long as the particles are capable of division. The seams are originally the jointed structure of the ledges, and ultimately the natural cleavage planes of the constituent minerals. The visitor may search in vain over Mt. Washington for any evidence of transported rock, save what may have been brought by human agency; and a few minutes' walk over the fragments will prove what a difference there is in the distribution of blocks of stone, by the action of frost and gravity combined, as compared with the arrangement of water-worn stones in a river, or the scattered boulders of drift origin. The house in the view is known as the *Tip-top*, built of fragments similar to those by which it is surrounded. The view was taken before so much of the summit had been covered by edifices as is now apparent to the visitor.

Fig. 10 will give a general idea of these blocks of stone, when viewed from some distance below the summit. Though taken in the winter, when the interspaces were filled with snow and ice, the effect is the

same to the eye as in the heliotype. On walking over the mountain, one can observe every stage of the process of decomposition. At first there may be a ledge, with pieces slightly removed from it. Next, one will be troubled to decide whether a series of fragments occupies the original space of the ledge, so that the position of the strata can be accurately determined, or whether the blocks have been removed out of place. In other piles there will be no question that every trace of the original stratigraphical structure has vanished. From these heaps there is an unbroken series to the piles of angular gravel and sand, which have resulted from continued decomposition. The extreme is where the sand

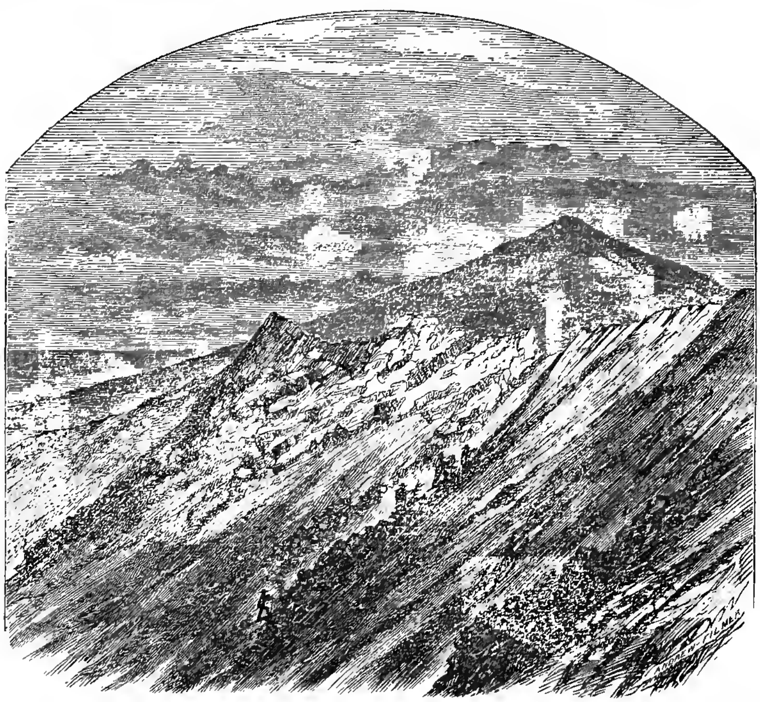


Fig. 71.—VIEW ACROSS THE RAVINE SOUTH OF MT. ADAMS.
Mt. Washington rises back of the débris.

has allowed vegetation to grow, and to accumulate a mould fitted for the development of the few hardy flowers and miniature trees of the alpine district.

The more common case of disintegration through frost may be seen along the sides and at the bases of precipices. Several of our figures

illustrate the process. Consult figures on pp. 12 and 28, and Figs. 31, 36, 63, 71, 72, 79, and 82 to 86.

An intermediate step in the process is illustrated in Fig. 71, the type of a very common state of things among our high mountains. The loose blocks accumulate so abundantly that most of the precipice has disappeared, and the fragments assume their natural angle of thirty-five degrees with the horizon, so as to render walking up the slope a matter of considerable difficulty. The one who goes first disturbs the equilibrium of some loose block, and it rolls down the hill, greatly to the discomfort of those who follow. These fragments are slaty. When granitic in character, and the disintegration has proceeded further, slides often result. After the rapid, thorough saturation of the gravelly mass with water, it becomes semi-fluid in its properties, and great portions of it slide to the bottom of the valley, often devastating fertile fields and destroying lives in consequence of the suddenness of the slipping. Another interesting view of the accumulation of fragments by frost disintegration appears in the copy of Mr. Morse's drawing of Carrigain notch.

Sculpturing of Granitic Rocks.

The first of the rocks, whose peculiar mineral composition gives rise to characteristic scenic forms, are the *Granitic*. The simplest case is that of a mountain like Chocorua (Figs. 31 and 61) or Pequawket (heliotype, Vol. II). It is a conical mountain, with a sharp summit, and not truncated like the volcano. Other examples are Mts. Monadnock, Ascutney, and Black, near the Connecticut in Vermont. The more complicated cases are where several conical peaks are grouped together. The two Percy peaks in Stratford afford a very fine example, as shown in a heliotype illustrating Chapter XIX. Others are the Stratford and Columbia peaks, numerous eminences in Essex county, the Orange mountains east of Montpelier, Vt., Profile, Tremont, and Haystack in the Saco valley, Crawford, Resolution, Iron, and others north of the Saco, Tripyramid, several others in Pemigewasset, Gunstock and Belknap, Red hill, Green mountains in Effingham, Moose mountain near Wolfeborough, Iron-ore hill near Haverhill, range of mountains in the west part of Benton, Mote mountains in Albany, and others.

The origin of the conical form may be due to three causes:—First, to the original shape of the materials. Our granite mountains have been erupted from below, and, when the entire mass is limited in amount, it would naturally be conical, the pasty substance tending to flow centrifugally from the vent. Secondly, the tendency of denudation is to wear away the summits of mountains. The forces act powerfully upon the exposed ledges at the tops, and the fragments will seek the bases of the hills, thus tending to the cone in form. Thirdly, the more energetic action of denudation in granite mountains is caused by a sort of concentric structure in cliffs. A good example occurs in Benton, near the summit of the Boston, Concord & Montreal Railroad, as one looks northerly upon the steep side of Owl's Head. Another may be seen in the

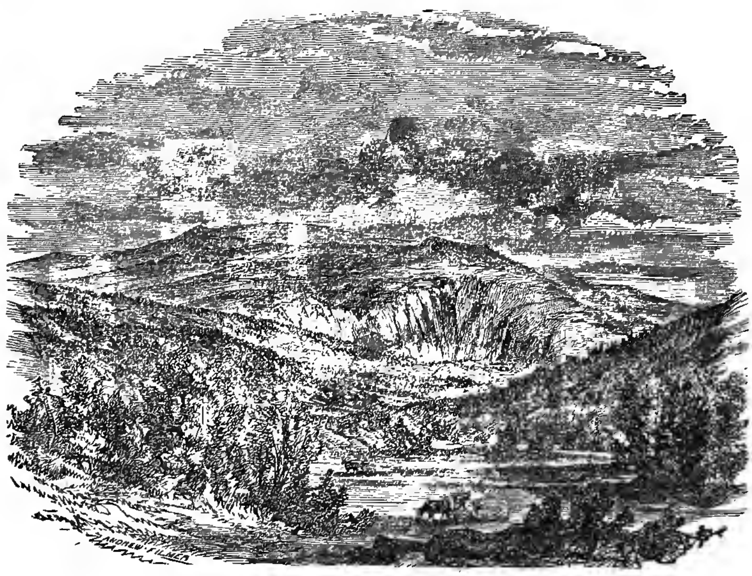


Fig. 72.—WELCH MOUNTAIN, FROM CAMPTON.

heliotype of Eagle cliff in Volume II, where the vertical wall of Profile mountain, on the left-hand side, shows the concentric, nearly vertical, slabs of granite peeling off and falling to the base of the cliff. The steep sides of Carrigain notch (see sketch) have been produced in the same way. The right-hand slope in Fig. 9 shows the base of a cliff opposite the Willey house, where similar action has taken place. A heliotype shows the same thing upon both sides of the Notch, in the

view down the valley from Mt. Willard. Fig. 72 also illustrates this tendency to split, less perfectly than some others; but the steep sides show where great masses of granite have been excavated, and the fragments washed down the tributaries of the Pemigewasset. The contrast in the kind of rock may be seen by the presence or the scantiness of vegetation, as well as by the position of the granitic piles in the background. The bare rocks exhibit many harmonies of color, offsetting the grays with neutral hues of blue and white, which, at sunrise and sunset, are intensified.

This tendency to split does not extend very deeply into the rock. It seems to be induced largely by the action of the weather, and has been observed about the Quincy (Mass.) quarries by Shaler, and also by Hunt. Perhaps a similar action is that made of practical service in removing boulders from a field. The farmer builds a hot fire over the granite blocks he wishes to remove. Then, by throwing water upon them while heated, large flakes scale off, and thus rocks too large to be transported bodily can be removed in a very little while. The flaking off always conforms to the surface of the stone, very much like the clearing of the larger masses from cliffs. I understand the arrangement of the Concord and other granites, in flat sheets, as seen in the quarries, to be quite a different phenomenon.

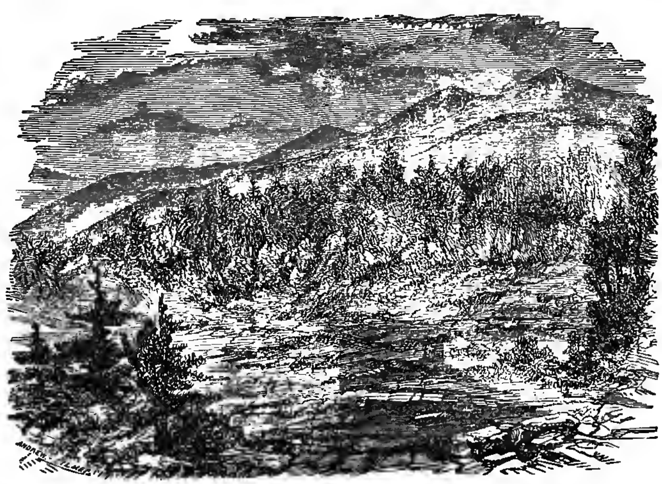


Fig. 73.—LAFAYETTE RANGE, FROM THE FLUME HOUSE.

In Fig. 73 the granitic slopes observable from the Flume house, upon the western side of Mts. Lafayette, Lincoln, and Liberty, are represented. The very apex of these mountains is composed of compact feldspar, which disintegrates the same as granite, and therefore has not varied the typical form of the decomposition.

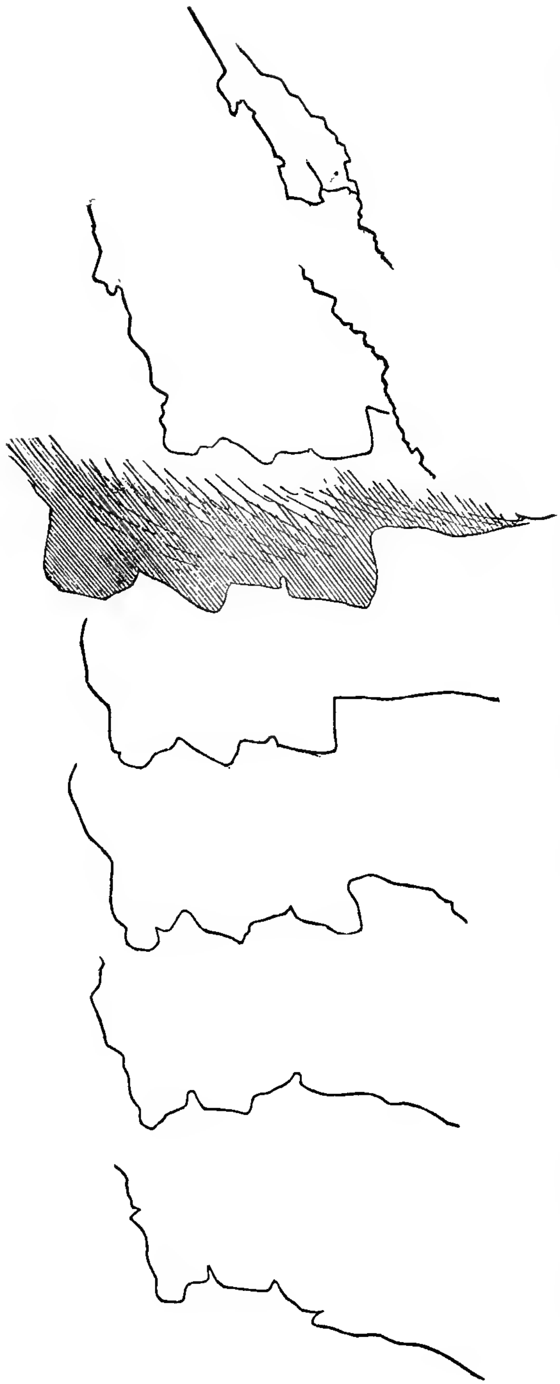
From the Flume house one can look squarely across to the depression between Mts. Liberty and Flume and perceive the same granitic roundness, as well as in the Coolidge mountains farther south. The view in the sketch is a very faint approach to the view of the *Aiguilles* of Mt. Blanc from the vale of Chamouni, for the great extent of the base of the Lafayette mountains conceals the proper proportions of the summits from this point of view. If one climbs the small Mt. Pemigewasset, back of the Flume house, he will see this range in all its grandeur. There is a carriage-road to its summit from the hotel.

At this point it may be well to call attention to a peculiarity of certain granitic mountains exhibited upon our heliotype of the White horse ledge in Conway. It is traversed by lines streaming down from the summit towards the water of Echo lake. Similar lines appear in photographs of the South Dome of the Yosemite valley in California, and other similar bluffs. At first I thought them due to a peculiar structure of the rock,—perhaps vertical joints; but a nearer inspection shows them to be the result of rain-water flowing down the cliff, and renovating certain parts of the vegetation, and in others changing the shade of color. This cliff also shows a little tendency to cleave off concentrically. The nearness of this cliff to North Conway, and the beautiful reflection of it in the waters of Echo lake, render it a place very attractive, and much frequented by visitors. The resemblance of the lighter markings, on the right-hand side of the view, to the head and front part of the body of a horse, is really too indefinite to render the name an appropriate one. The ledge must be about 700 feet high. The one to the north is 960 feet above the Saco meadows.

Profiles. Among the accidental shapes, left by the granite on the cliffs back of Profile lake in Franconia, is the outline of a human face known as the *Old Man of the Mountains* (Fig. 45), and one of the most attractive features in the landscape in this part of the country. Most of the facial features are present,—the forehead, eyebrows, nose, mouth, and chin,—and well proportioned to one another. (Fig. 74 is roughly copied from the lithograph of Oakes, after a drawing by Sprague.) It has been placed by nature in a very convenient place for exhibition, standing in relief against the sky, and in picturesque harmony with its surroundings. It can be seen to advantage only in one line, from the lake up Eagle cliff

in a northerly direction. If you go a short distance either to the right or the left of this line, the shape of the face is distorted, and disappears.

Fig. 74.—THE PROFILE ROCK.



[As you pass to the right.

Fig. 75.—CHANGES OF THE PROFILE.

As you pass to the left.]

The profile is made of three jutting masses of rock, in different vertical lines. One piece makes the forehead, the second the nose and upper lip, and the third the chin. The rock is about 1200 feet above the lake, and 40 feet in length. Mr. Oakes puts the length, from the top of the forehead to the lowest point of the chin, at twice this figure. Its length was measured by the young men from Dartmouth college, in our exploring party of 1871, and found to be from 36 to 40 feet.

The rock is an ordinary granite, quite friable from decomposition. Judging from the specimens, I should say that portions of the pieces composing the profile are liable to fall at any time. The disintegration has gone on so far that the rock crumbles under the pressure of one's fin-

gers. The ledge is extensive, however, and may stand for scores of years; but I would advise any persons who are anxious to see the Profile for themselves, to hasten to the spot, for fear of disappointment. I should also question the presumption entertained by many that the Profile was probably known to the aborigines, who are supposed to have gazed upon it with superstitious awe. They have given us no legends concerning it; and its easily decomposing character would suggest that it may not have existed in its present shape for many centuries back. The first notice I can find of it is contained in a description and figure, by Gen. Martin Field, published in 1828 in the *American Journal of Science*, I vol. xiv, p. 64.* It was discovered not long previously in laying out the road through the Notch. The proper place to see the Profile is on the carriage-road, about a quarter of a mile east of the Profile house, and close by the lake. The figure varies from different points of view. Seen from the road, the expression is somewhat severe and melancholy. Views taken from nearer the object, up the pile of fragments, show him to be much better natured. Oakes remarks that the "face of the 'Old Man of the Mountains' is set, and his countenance fixed and firm. He neither blinks at the near flashes of lightning beneath his nose, nor flinches from the driving snow and sleet of the Franconia winter, which makes the very mercury of the thermometer shrink into the bulb and congeal."

In passing to the left, the chin sharpens; then the teeth, as it were, have fallen out, and there is a cap over the forehead. In continuing to the left, the lower part of the face begins to fall away, and is entirely out of sight, while the cap and nose remain essentially entire. The nose and face become flattened in passing to the right, and soon only the forehead remains. The original of the vignette was copied from a photograph.

This face has been celebrated in Hawthorne's tale of "The Great Stone Face," and in "Christus Judex."

Upon Mt. Jefferson there is another arrangement of rocks bearing some resemblance to a human countenance, with a cap on the head. It is known as the "Sentinel," and is rarely visited. It is formed by schis-

* This figure is such a curious exaggeration of the rocks, that I have procured a *fac-simile*. The reader will please to compare it with the vignette on the title-page.

tose rocks. In the gate of the Notch, near the Crawford house, several inferior profiles have been pointed out, as the "Old maid," "Young man,"

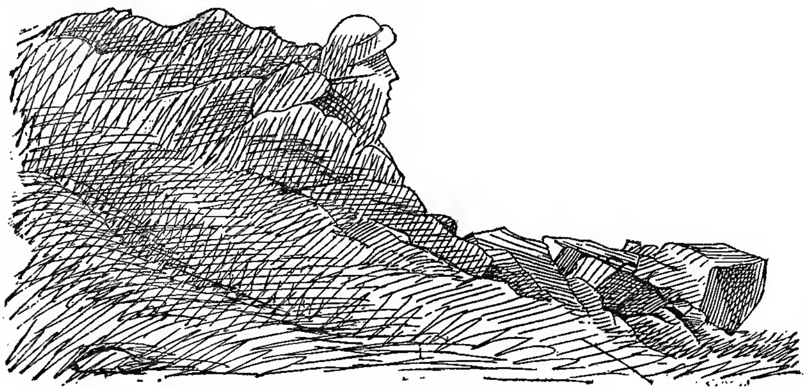


Fig. 76.—THE SENTINEL.

"The baby," etc., but the resemblances are not striking. Perhaps the best rocky face in the state, next to the Profile, is the "Old Man of Dixville."

Features of Long Ranges of Schist.

The more common variety of our scenery is based upon modifications of long reaches of micaceous schists. The scenery is less pronounced than that characteristic of a granitic foundation, since the rock decomposes with difficulty. The shapes of the mountains of this rock depend chiefly upon their original position, as determined by elevation. Where the forces have acted normally, there results a long range with rounded surface, like a mid-ocean wave of corresponding length. In the case of dislocations, the mountains will stop short at the line of fracture. When more than one series of elevations has affected the mass, the composite character of the resulting eminences may be observed.

Such features of elevation and disturbance as have been noticed about the Mt. Washington range are of considerable consequence, since the district is better known than most others, and presents the grandest elements in our scenery.

There are two ways of looking at this range,—from the side, or from the ends, somewhat tangentially. Of the former, the views from Bethlehem, Littleton, Whitefield, and the vicinity of the Fabyan house are

the best from the west, unless you choose to climb various peaks and mountains. The near easterly view from the Glen house on the east is quite imposing. As the country is entirely unsettled on the east, in the immediate neighborhood of the mountains, it is not so easy to get a satisfactory view from this quarter; but one nearly as good may be obtained from the hills back of Jackson, of which I had hoped to present a heliotype for the frontispiece, but have been unsuccessful, because of the difficulty of obtaining a clear negative at such a great distance. From this point Washington is seen to stand much higher than his brother peaks, and the deep ravines on his south-eastern side are clearly defined.

Our heliotype from near the Fabyan house, about a mile and a half east, gives us a good view of the mountains, as a range, from Jefferson to Clinton. Washington is notably the highest of the peaks, showing a slight depression in the middle of what is properly the summit. The west side is cut by two rough valleys. On its north-east ridge may be seen the winding course of the railway. On the left, Mt. Clay seems quite insignificant. Of the peaks on the right of Washington,—Monroe, Franklin, and Pleasant,—the latter is the most conspicuous, because higher than those immediately adjacent, and the curious hollowing out of the front side by streams. Fig. 25 presents a part of this heliotype, as sketched by hand. The artist plainly exaggerates the relative heights of the several summits and ravines, as may be seen by carefully comparing the sketch with the photograph; but it is almost impossible to avoid exaggerating any magnificent view with the pencil. The mind compels the hand to reproduce the *effect* received by an inspection of the scene, and it cannot be done well in any other way.

In Fig. 77 we have a view of the Mt. Washington range from Milan, a direction slightly east of north. The central peak, seemingly the highest, and with an immense piece hollowed out, is Mt. Adams, with a double summit. Beyond, to the right, is Mt. Jefferson. The most prominent peak on the left is Mt. Madison. Back of the deep cleft, called King's *ravine*, between Adams and Madison, faintly rises Washington. In the foreground the Androscoggin valley shows itself, first running towards Madison, then turning south-westerly towards Adams, before curving around the farthest of the smaller hills to flow out of the

scene to Gorham. The hamlet directly in front is Milan. This was one of the favorite points of view with Starr King, who regretted that so few persons among the great travelling public ever attain to it. It is of easy access, either by a carriage-drive of a dozen miles from Gorham,

Fig. 77.—WHITE MOUNTAIN RANGE, FROM MILAN.

or a walk of a mile or two from the Milan station on the Grand Trunk Railway. There is a country inn at Milan, where travellers are always welcome.

These views give the idea of a long range with minor undulations.

The suggestion has been made of the existence of a fault in ancient times, which lifted this range abruptly above the Saco valley, on the side of Mt. Webster. The change from the Androscoggin valley is less abrupt to Madison, there being a gradual descent through the intervening Pine hill, not shown in the last figure. The action of the Androscoggin river has deepened the gap naturally existing between Pine hill and Mt. Hayes; but we have here no evidence of an upthrow or downthrow on either side.

There have been not less than three attempts of the forces of nature to throw up this range. The first evidently produced a wave-like ridge, much like its present form, but not so elevated. One of the others acted in the same direction, and therefore cannot be distinguished from the first in its effects. But the third force pushed from a direction at right angles nearly to the others. Its effects can be conceived by imagining an ocean wave to become fixed, while it is allowed to have a plastic constitution. Supposing, now, that some force pushes this plastic material in the direction of its length, it is clear that there will be a ridging up which will tend to elevate disproportionately certain parts of the wave. Such action has taken place in this range, as its indications are manifest in the contortions of the strata, and its effects must have been permanently impressed upon the figure of the mountain.

I am disposed to think that Washington, Jefferson, Adams, and Madison owe their conical shapes to the crushing action of the last mentioned of the three forces of elevation. If you examine carefully the positions of the strata upon these summits, you will perceive great irregularity and constant variation, just as if the plastic material had been crowded into heaps. But all the notches have been intensified by erosion, as well as the valley of the west branch of the Peabody river, shown conspicuously in Figs. 63 and 70, and less so in Figs. 79 and 85.

Another marked feature of the higher regions is its plateau character. It is best seen in the heliotype view of Mt. Washington from the southeast. On descending to the Lake of the Clouds, the explorer will find a very flat region, running out easterly into Boott's Spur, and northerly along the east side of Washington. The Great Gulf, between Washington and the three contiguous peaks of Jefferson, Adams, and Madison, is only a gorge cut out of the plateau, as we can easily imagine on looking

northerly from the Tip-top house, or at Figs. 79 and 85. But the view from the south-east shows the plateau best, and if it had been taken from a point a little farther east, the feature would show itself more prominently, as in the last of Oakes's lithographs. The abyss in front is Tuckerman's ravine, with tributary scallopings on the north-west sides. The erosion has been vertical, just as in a gorge worn out of a level plain. It is impossible to descend with safety down the sides of this ravine in most places. And the accessible portions have been rendered less precipitous by the accumulation of loose material, through slides and atmospheric disintegration. Oakes's gulf and Huntington's ravine are other deep gorges excavated out of this plateau. This table-land is less than ten miles in length, and somewhat over 5000 feet in elevation.

We think, therefore, the proper structure of the Washington group of summits is best expressed by the supposition of a plateau, out of which

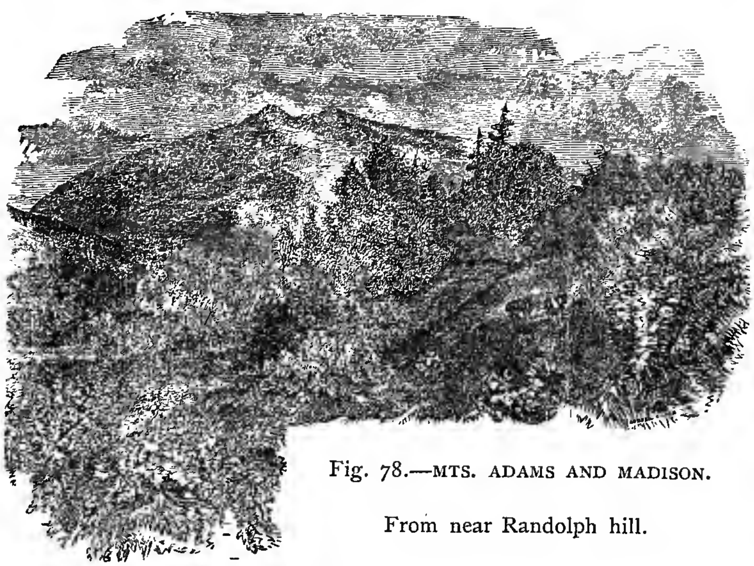


Fig. 78.—MTS. ADAMS AND MADISON.

From near Randolph hill.

four great ravines have been excavated, and upon which lateral forces have piled up comparatively inferior heaps of contorted rock, constituting the presidential summits. With these suggestions in mind, the tourist will easily see the reasons for the special fashioning of every elevation and depression in the Montalban area.

The modifications induced by stratigraphical structure are perhaps

less important than what have been described. The shape of the range is like that assumed by hills with a monoclinal dip, while the structure is that of an inverted anticlinal axis. There would also seem to be a synclinal basin on the east, separating the range from the Carter mountains in Bean's Purchase. The structure of the latter line of elevations is not well understood. It is often the case on Washington that the inversion does not appear at the bottoms of the great ravines. In the Peabody River (west branch) gulf the dip is easterly, while high up on the mountain's flank the reversed north-westerly inclination is apparent.

The great water-shed of the state, south of Franconia, is maintained in its present position, for stratigraphical reasons. The axis of the ridge is a very hard, unyielding granite, which has sternly resisted all efforts at thorough disintegration from the earliest times. It is an interesting fact that this range should be essentially parallel to the anticlinal ridge of the Green Mountains, both being of nearly the same age.

A few other interesting views of the great range of mountains may be noticed here. On page 3 Mt. Madison is seen to loom up majestically, as it is viewed from Shelburne. Fig. 60 is a similar sketch, from the

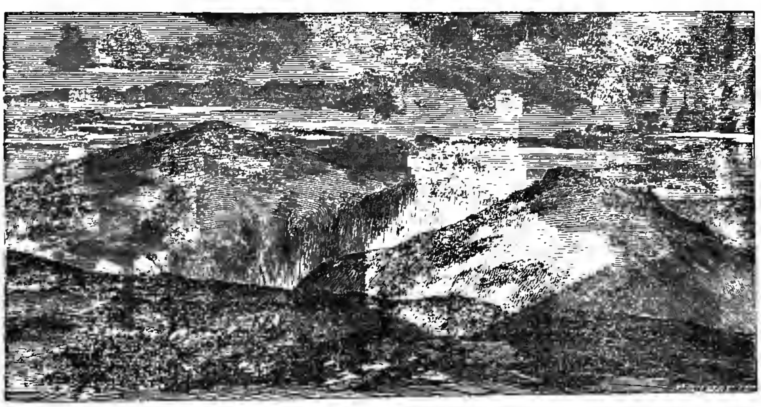


Fig. 79.—WASHINGTON, CLAY, AND JEFFERSON, FROM ADAMS.

Lead Mine bridge, one of the favorite localities to be reached from Gorham. Fig. 67 seems to be from a point intermediate between the others. In all of these, Washington appears quite inferior by the side of the more conspicuous eminence.

The views from the north of the same mountains give a greater

breadth of base than those from Shelburne, as in Figs. 78 and 44. The first represents the view of Mts. Madison and Adams from Randolph hill, about five miles from Gorham in the Moose River valley. In this neighborhood one can study to advantage various features about the bases of the mountains, that help make up a perfect sketch,—the ragged edges of ravines, outlines of the rocky abutments, and the valleys made by the streams and clefts in the ledges. These forms are such as are peculiar to schists. In Fig. 44 the base seems broader; and now Mt. Washington has made its appearance in a small cone between and back

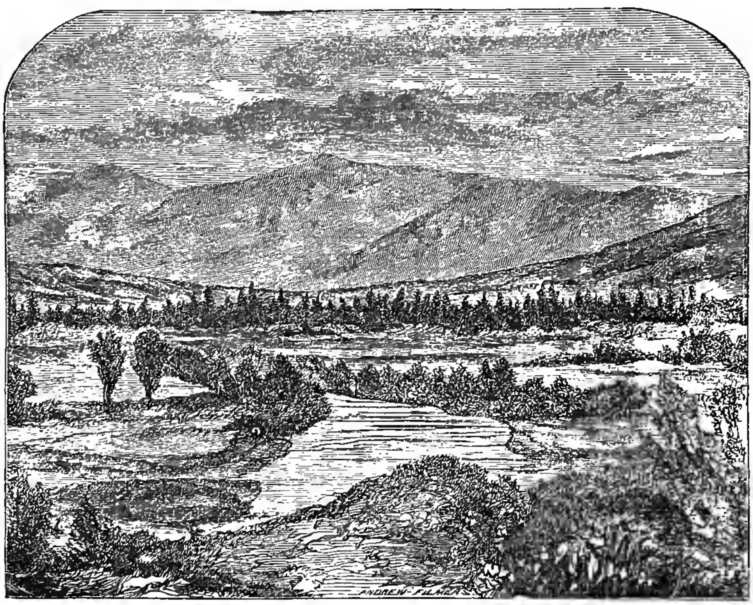


Fig. 80.—WASHINGTON RANGE, FROM CARROLL.

of the others. The summits lie in a semi-circular line, with reference to each other.

Midway between Bethlehem and the Fabyan house is a view of the Washington range in Carroll, that is much admired (Fig. 80). It is from a point below the Twin Mountain house, though not far distant; and one has the advantage here of seeing the range behind a level foreground consisting of the Ammonoosuc meadows. The range is of schist, while the foreground rests upon granite. The view may be compared with that in Fig. 25.

THE ROUTE OVER MADISON, ADAMS, AND JEFFERSON.

The rush of travel to Mt. Washington passes up either the railway or the carriage-road from the Glen. Every one desires to see these thoroughfares, and the fine views attainable from them; and perhaps the fundamental idea of the mountains should be first apprehended from these directions. The great conveniences of these routes are causing the charming drives in other directions to be forgotten. Those who have the leisure should not fail to traverse the road from Gorham to Jefferson, on the north side of the mountains, as they will then best catch the spirit of the hills, especially if they should leave all travelled routes behind, and clamber over the rocks to the summits of the rarely visited peaks. Any lover of mountain scenery must yearn to stand upon the top of Mt. Adams, as he gazes in that direction from the Tip-top house. I have a few sketches setting forth certain peculiarities of schist structure, which will also illustrate a way of reaching Mt. Washington over Mt. Adams from Randolph, and may be described appropriately here. Formerly there was a path up Israel's river, passing over Mt. Jefferson, known as the Lancaster path, but it is now as little frequented as the Davis bridle-path to the summit over Mt. Crawford. They are both so overgrown as to be hardly distinguished from the surroundings. The Lancaster path, however, is only partially the same with the one under consideration.

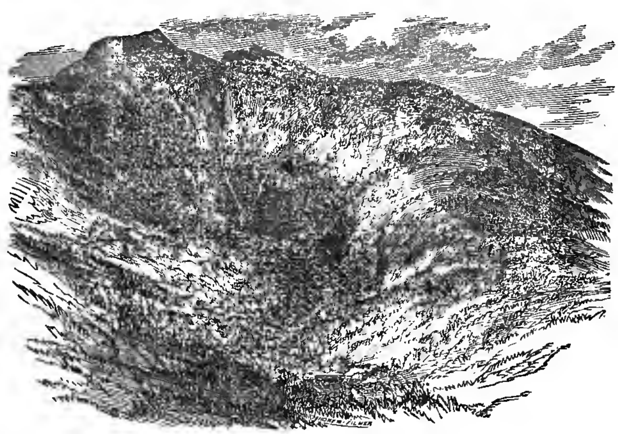


Fig. 81.—KING'S RAVINE IN MT. ADAMS.
From Randolph hill.

In Fig. 81 is a near view of an immense cleft on the north side of Mt. Adams, noticeable also in Fig. 77. This seems almost inaccessible from below. In ascending to it there is no unusual difficulty, more than the

customary labor of threading the forests in any direction among the mountains. Adjoining the streams there are always obstacles like fallen trees and a thick growth of alders; and, in climbing the steeper ascents, a thick growth of moss conceals many deep chasms between blocks of stone;—but attention will prevent any serious calamity. It is no easy task to pass over the side of the great cleft which looks so smooth. That beautiful green short growth, which so pleasantly arrests the eye upon the range, as everywhere else, is a nearly impenetrable thicket of stubbed spruces and crooked poplars. Fortunate is the person who can emerge from it with whole garments. In the sketch, tiny streams are seen to flow down the upper part. At the very head of this cleft is a wall that bars all further progress in that direction, as exhibited in Fig. 82. This view is seemingly about midway in the gorge, above the tall trees. Towards Randolph there is a uniform, sharp slope to the road. Above, the walls tower perhaps 1500 feet immediately under the head of the mountain, which cannot be seen by the climber. The edges are more jagged than the graceful curves about Tuckerman's ravine, and the cleft possesses more elements of grandeur. As this ravine was first described by Starr King, it seems proper to restore the name, which, though placed upon the county map, seems to be generally forgotten. It

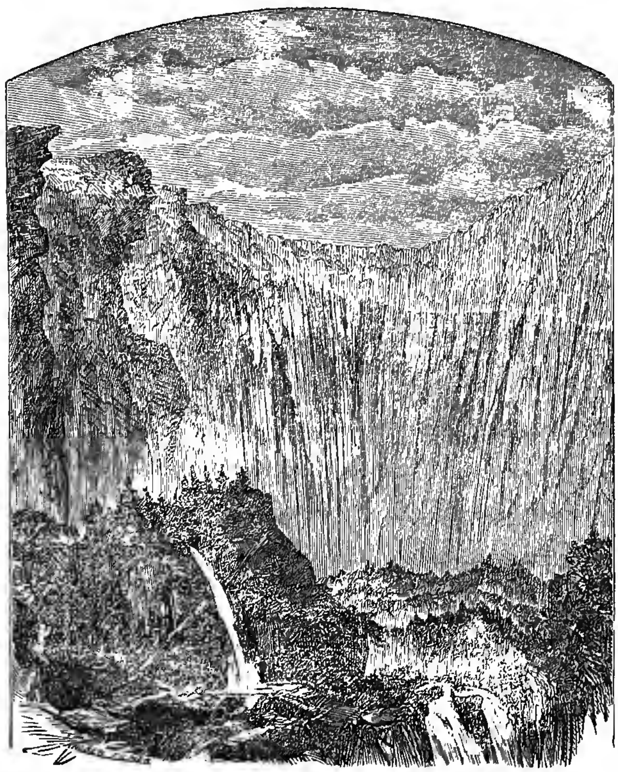


Fig. 82.—HEAD-WALL OF KING'S RAVINE.

should be *King's ravine*, and it is described in glowing terms by almost its first explorer in the *White Hills*. It may have been termed Adams ravine in a few places in this volume.

The final pull through the ravine may be represented in Fig. 83. The fragments coming down from Mt. Adams are on the right, and a few jagged ledges on the left. Between, there is a grassy growth of a few feet, presenting in the view a resemblance to an artificial road. Our route has led us up the east side of the ravine to the notch between Madison and Adams. Fig. 84 may illustrate a portion of it near the gateway. The rocks on the right overhang the traveller with a threatening aspect, while the slope on the left is more inviting, with a scanty growth of grass. The fragments are coated over with gray lichens, save along a few lines where rolling stones have plowed a furrow.

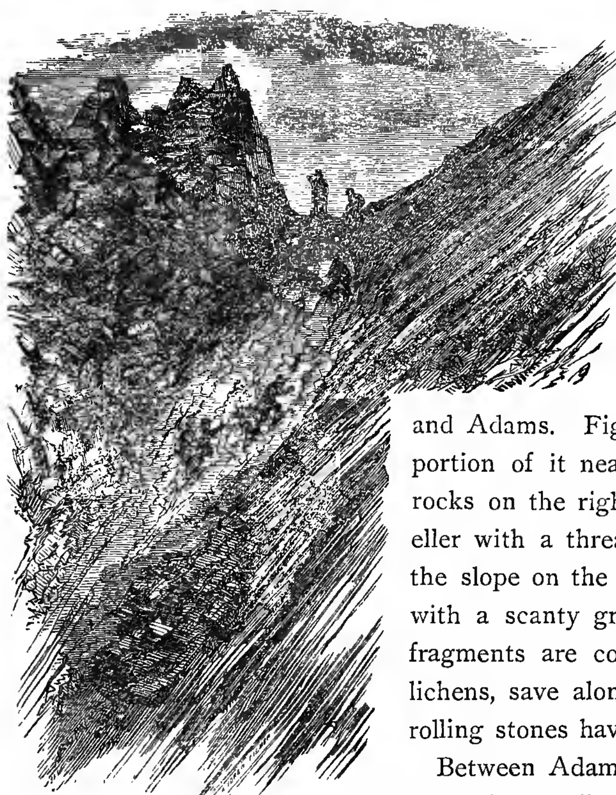


Fig. 83.—GATEWAY OF KING'S RAVINE.

Between Adams and Madison there is a deep valley containing a small pond of water. On rising up to the side of Adams from the gateway, one is surprised to see so sharp a cone as is presented by Mt. Madison. (See Fig. 69.) With a cloud below, and the mountain standing out by itself, the effect is that of an enormously high, sharp mountain from this point of view. An easier way of reaching Madison is to ascend either from Martin's Location (H. D. Copp's), or from the summit of the northern Pinkham Notch road. The crest of the slope, if followed strictly, will bring one by the shortest road to the summit, from the last mentioned starting-point, though the spruce

growth is fearful to traverse. Ledges are common at the summit, with obscure glacial markings. The strata are immensely contorted here, as well as on the ridge running towards the Half-way house on the Glen carriage-road, and, in fact, everywhere over these highest peaks.

On coming back to the Notch above Fig. 83 (for we have made a detour to Madison), a portion of Adams stands up very lawlessly upon

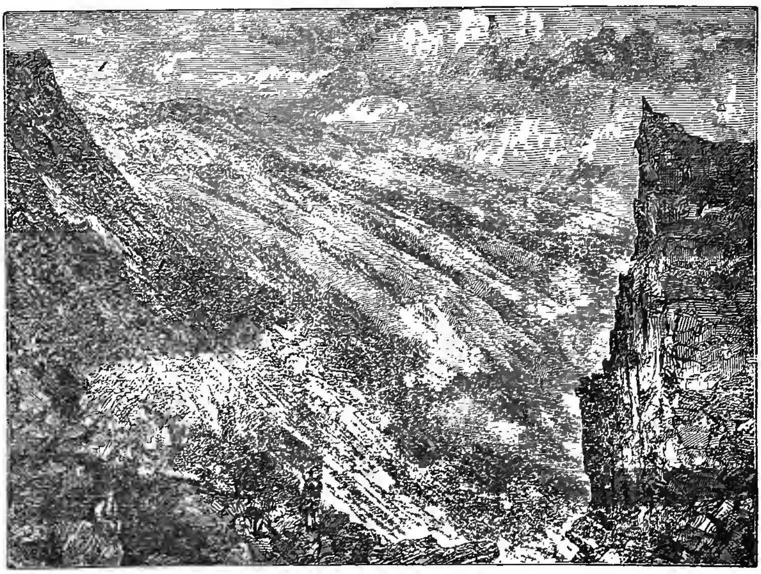


Fig. 84.—CLIFFS IN KING'S RAVINE.

its west side, and exerts a strange fascination over the tourist. The rock is bleak and bare, as is nearly every portion of these summits, but gives the impression of softness. This feeling may be due to the curvatures in the strata. Ruskin, in his *Modern Painters*, maintains that one secret of Alpine grandeur consists in the existence in the needles of infinite curves, or those that never can return into themselves, like the parabola. The principle may be applicable here, as it certainly is in many other parts of the range.

Mt. Adams does not, like Madison, present ledges upon its summit. Frost has broken down the rocks, and fragments are strewn universally over the cone. You can find one comparatively small block, standing above every other one, at the very apex. Hence it is impossible to say whether the great, rounding ice-agency has pushed over the summit of

Adams. It is at the same level with the highest supposed foreign pebbles on Washington, and therefore may have never been covered by moving ice.

Adams has a double summit, as appears in Fig. 81. We may, for convenience, call the lesser one, which is farther to the south, Mt. *Quincy* Adams. It rises out of a very level space, perhaps a part of our plateau described above. The view from Adams is very much the same as from Washington, save that we see the highest of the White Mountains, which cuts off the south-western view, as would appear from Fig. 71. The country to the north is also more exactly defined. In a visit to Adams, made about the first of May, at the time of our occupation of the summit of Mt. Washington for meteorological purposes, I found the path more comfortable than in summer, because snow filled up many of the lacunæ between the rough blocks. On a subsequent occasion, tourists visiting Adams could plainly hear shouting upon Mt. Washington, a distance of four miles in an air line.

The rest of the route to Washington is less exciting than up King's ravine, but oftentimes adventurous and everywhere delightful views are afforded. Upon Mt. Jefferson is the curious castellated ridge, shown on page 28, and also the Sentinel (Fig. 76). The lowest part of the notch between Adams and Jefferson has a very narrow summit, the ground sloping steeply on both sides from a mere line. The uniform gray tint of the rocks on the north flank of Jefferson is relieved by many pure white blocks of quartz. The hummocks of Mt. Clay show more regularity of stratification than any of the other peaks, while the slope towards the gulf is precipitous and impassable.

The Ascent of Mt. Washington.

The three thoroughfares ascending Mt. Washington, most commonly used by tourists, are the Crawford bridle-path, the carriage-road from the Glen, and the railroad from Ammonoosuc station. The latter will very soon connect with the Boston, Concord & Montreal Railroad, so that one can ride from Boston to the summit, with only one change of cars, in ten hours' time. The Davis bridle-path from the Mt. Crawford house, the foot-path to Mt. Pleasant from the Giant's grave, the Lancaster way, and the older roads from the Glen and Fabyan's, are now

obsolete. I have marked some of them upon the general map, for their historic interest.

Ascent from the Notch. It is rumored that the Crawford path is soon to be made into a carriage-road, so that one can pass directly from the Glen to the Notch, over the summit, with the same team. Such an improvement would greatly enlarge the ability of tourists to explore the mountains. The present bridle-path starts from the Crawford house, passes up a valley on the north-west side of Mt. Clinton to its summit, thence over Mts. Pleasant and Franklin, on the east side of Monroe, past the Lake of the Clouds, and up the cone of Washington.

This path has some advantages. After travelling a couple of miles in a forest, one comes out upon an open ridge, and can enjoy magnificent views the rest of the way, especially of the side ravines and of Mt. Washington. The absence of much vegetation makes the tops of these mountains a natural pathway. Cloud effects are better on this route; and, should the highest summits be obscured, one feels repaid for the journey by the glimpses obtained on the lower peaks. Mt. Pleasant is known by its rounded summit, and greater elevation than the peaks on either side. When reached by this path, the surface appears like a smooth field, sloping gently from the centre outwards in all directions. The view north-easterly is a notable one. First is the long, bare top of Franklin, with the serpentine thread worn by the horses' feet running its whole length. Next, the double, ragged peaks of Monroe present a wide contrast. The natural slope of the strata north-westerly can be detected through all the rubbish covering them. On the right is another view of the great elevated plateau,—that part known as Bigelow's lawn,—overlooking Oakes's gulf. Washington towers far above everything else, and displays to advantage the excavations upon the west side, with the ridge on which the railway ascends to the summit.

One of the heliotypes represents the larger of the Lakes of the Clouds, partially filled with ice (Vol. II). These are two small tarns 5000 feet above the sea, the sources of the Ammonoosuc, and in the saddle between Monroe and Washington. Alpine vegetation borders them, and they have been chiselled out of the solid rock by the drift. The ice-markings are plain in their neighborhood to the height of 5200 feet.


Mt WASHINGTON FROM S.E.

The Railway. The lower station of the Mt. Washington Railway is known as "Ammonoosuc," and consists of the necessary buildings for the accommodation of the road. The station-house is on the west branch of the swift Ammonoosuc stream, which has descended over 2000 feet since leaving the Lakes of the Clouds, about three miles distant. The stream is crossed by trestle-work about fifteen feet high; and the track commences with the grade of 1700 feet to the mile. Place the end of a ladder thirty feet long upon a fence ten feet high, and an adequate idea of this inclination will be exhibited to us. It does not continue, however, beyond 300 feet. At three fourths of a mile is the first water-station, near the "Cold spring." The grade becomes steeper again at the "Waumbek junction," one mile and eight rods distance from and 1242 feet higher than the starting-point. The road is straight thus far, and forest trees of ordinary dimensions have been cut for its passage. But now the trees are smaller; the track curves; and soon there is a small cut through a ledge. With the top of the trees the trestle-work known as "Jacob's ladder," 2800 feet above Ammonoosuc, is reached. A view of this portion of the road, with the mountain engine upon it, has been given opposite page 82.

This trestle-work is at one point thirty feet high; and the track has an elevation of more than one in three for 300 feet. The traveller has been noticing the changes in the shapes of the western mountains in the ascent, and has observed the curious outline of the Lafayette range rising up behind the Twin mountains. On the north he may see the beautiful south-westerly slope of Jefferson, and on the south the several peaks along the Crawford road. Westerly, the views of the valleys are charming. His attention will now be divided largely by the curious angular stones and the sub-alpine vegetation suddenly brought under his notice. Should the weather be unpropitious, this is the place where the powerful winds of the upper current will begin to be felt, and clouds may shut out every bright prospect. Not far above Jacob's ladder the ridge between Clay and Washington will be reached; and the traveller can look down a thousand feet into the black gulf at the head of the west branch of the Peabody river. The rest of the ascent is comparatively gradual, and the distant views are beginning to absorb the attention. Something of the arctic desolation of the mountain itself is expressed in Fig. 10.

The Summit. The buildings upon the summit are quite numerous. There are a large hotel, two railroad edifices, the old Tip-top and Summit houses, and the observatory, besides two barns just under the crest on the south-east. The views in different directions now need to be obtained from several stand-points about the platforms and among the buildings. From favored rooms in the hotel the sunrise can be seen, without the necessity of leaving a comfortable room. The observatory is specially favored in its situation, as the finest views can be obtained from indoors. With the severe arctic climate of this locality, one naturally seeks for physical comfort to the neglect of the esthetic; but if both can be secured, the possessor should be doubly happy.

Most people are disappointed in the views from Mt. Washington summit. They reach the top about noon, and remain one, two, or more hours in the middle of the day, when there are no shadows. They are bewildered by the vastness of the panorama, perhaps insensibly. It may be that there is no one to point out particular features of beauty. The landscapes require considerable study to be properly appreciated. Let one take a map of New England, and trace out all the mountains west by name, then in other quarters. Let him realize that in one direction, one hundred and fifty miles away, the minute spire of Mt. Katahdin pierces the horizon, while opposite (the same distance) the remotest projection is Graylock in western Massachusetts. Beyond the Green Mountains are the clearly defined Adirondacks; on the north the great valley of the St. Lawrence. On the south-east, in a clear morning, he may, with a glass, see the ocean steamers in Casco bay. With this panorama before him, let the observer carefully note all the smaller peaks and valleys, study them out from their locations on the map, and he will become greatly interested. Except by a thorough inspection of what seem small areas, he cannot appreciate the immense number and variety of objects visible. He can spend a full month in observing, and discover some new feature every day.

The atlas contains a plate showing in outline the principal mountains and valleys, as seen in the sweep from this summit. The foundation of the sketch is a series of drawings with a camera, so that its accuracy can be vouched for. The more distant points have been exaggerated a little,—otherwise they could not be seen. The reader is referred to

this outline drawing for a description of many of the objects visible from Mt. Washington. These profiles will very materially aid any one in studying the topography of the surrounding country.

The most interesting features of one's stay upon this summit are derived from meteorological sources,—the sunrise and sunset, shadows of the mountain upon clouds and adjacent ranges, wonderful colors, shapes, and movements of clouds, the perception of the beginning and progress of storms, hurricanes, frost-work, variation in temperature and humidity, fluctuations in the barometer, conflict of winds and clouds, etc. Sketches of some of these phenomena have been occasionally presented in this

Fig. 85.—ADAMS AND MADISON, FROM THE OLD GLEN PATH.

volume, especially what is peculiar to the winter. A heliotype of this sort faces page 104, illustrating the coating of the summit with snow-ice in the winter. The first is a copy of a very distinct photograph of the Carter range on the east, but does not do justice to the subject. The other shows delicate frost-work upon the Bourne monument and the low trestle-work of the railway. Opposite page 112 are four more views, selected from those taken originally by Clough and Kimball in mid-

winter. We have here exhibited a picture of the anemometer used by the party in measuring the velocity of the wind; the Tip-top house when covered by ice; shrubs frosted in a somewhat different style, but more delicate; and a look in the direction of Winnipiseogee lake.

Carriage-Road. In starting from the Glen house, up the carriage-road, one hardly realizes he is climbing a mountain. The road is cut through the forest for about three miles and a half. At four miles the Half-way house is reached, and the rest of the way leads over bare rocks above trees. In Fig. 85 is represented the appearance of Adams and Madison from the old Glen path, perhaps two miles beyond the Half-way house. Being nearer, these mountains seem of mammoth proportions, while one greatly enjoys looking back to the more remote Carter range on the east into an entirely unexplored district. The southern angle of the road gives a glimpse into the deep ravines pointing southerly, passing into Huntington's. The road winds around, so that every yard of distance leads upwards; but the steepest grade is only sixteen feet in one hundred, the average being twelve.

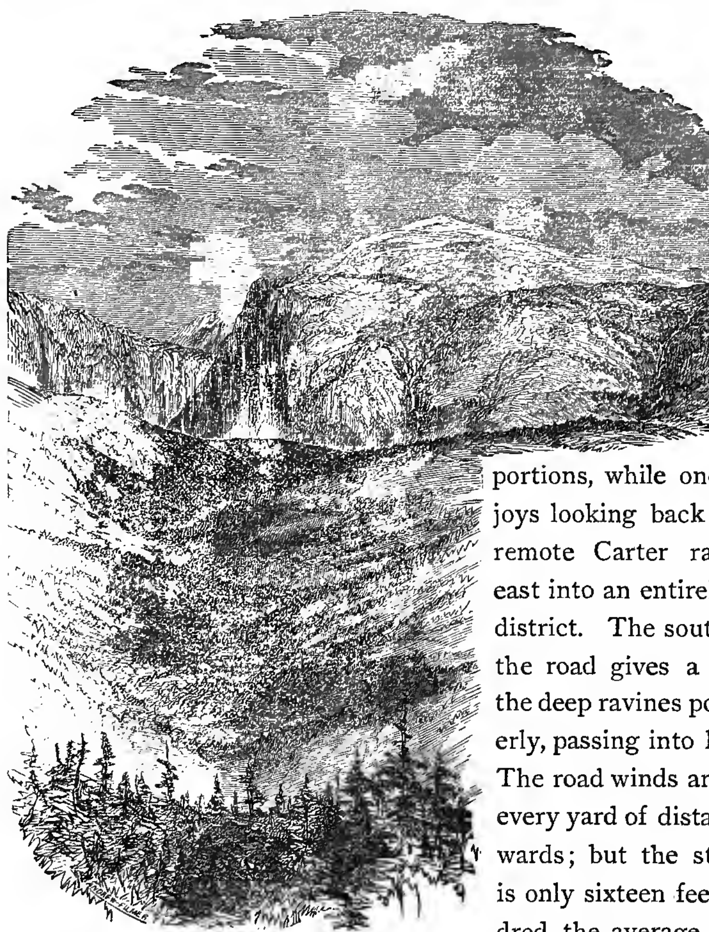


Fig. 86.—TUCKERMAN'S RAVINE AND MT. WASHINGTON.

Tuckerman's Ravine. This is the most celebrated of all the

ravines about the White Mountains, partly because of the presence of snow there all through the summer. Its position, in reference to the main topographical features of the mountains, may appear by referring to Plate C, page 338, to the representation of the mountains, and the general geological map in the atlas. It rises directly below the summit of Mt. Washington, having been excavated out of the plateau much in the manner of a gorge. The beginnings of the cleft may be seen in the heliotype of Mt. Washington from the south-east, while the general aspects of the whole ravine are presented in Fig. 86. The head is nearly two hundred feet below the summit; and the descent from the plateau is dangerous along the most feasible route, and impossible most of the way. The innermost part of the ravine is semi-circular, the outer cliff rising directly a thousand feet. After receiving the waters flowing from Huntington's ravine into it from the north, the gorge becomes much more open, and is hardly to be distinguished from ordinary mountain valleys. Two small tarns,—one known as Hermit lake,—rest high up the valley; and above them innumerable rivulets trickle down the cliffs, known as Raymond's cataract and the Thousand streams in several published stereographs. The cliffs are composed of andalusite slates, dipping at a moderate angle into the mountain north-westerly.

Tourists are fond of imagining this and the other deep ravines in the state as the product of some tremendous earthquake throe. They are more easily explained by the action of frost, gravity, and water-power. With the elevation of the mountains, there will be naturally a few lines of depression, which give origin to streams. In the colder seasons, the water freezing in the seams of the rock will detach slabs and blocks of stone. These, acted upon by streams, will eventually be changed to gravel and sand, and be washed down the mountain, leaving fresh surfaces for the renewed winter freezing. In this way, little by little, the work of excavation goes on, the deep, ragged ravines notching the mountains where the formation happens to be slaty and permeated with numerous joints.

The snow-arch is the feature which visitors delight to examine. The violent winter winds blow immense quantities of snow from the summit into this ravine, accumulating, it is said, to the depth of hundreds of feet. The enormity of the mass enables it to resist the genial influences of the

sun's heat for a long time;—hence it may remain in patches, in favorable seasons, even into September. Usually it is more or less arched, owing to the more comparatively rapid melting next the rivulets. Fig. 87 represents an unusual form, as it appeared August 28, 1861. The under surface is always uneven, the irregularities resembling the conchoidal fracture of cannel coal, flint, and other minerals. In August, 1855, the snow was said to be 294 feet long, 66 broad, and 15 deep, by tape-line measurement.

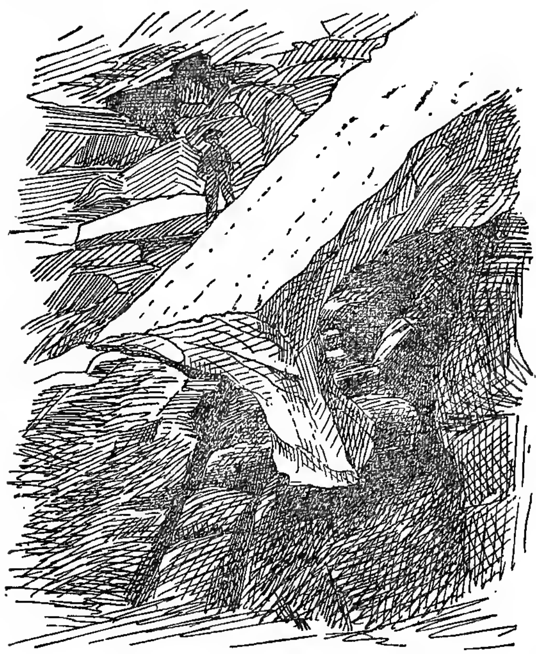
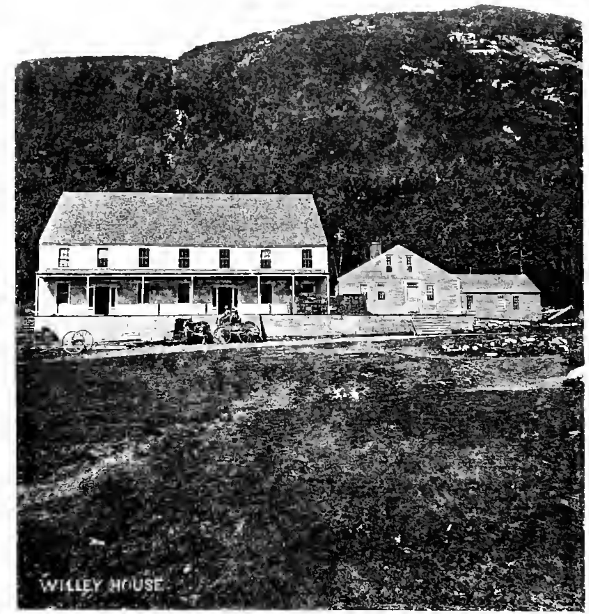


Fig. 87.—SNOW-ARCH IN TUCKERMAN'S RAVINE.

The Thousand streams unite with the snow-water, and form the head waters of Ellis river, a tributary of the Saco.

White Mountain Notch. The term "notch," as used in the Northern states, designates mountain passes, corresponding to the "gaps" in the Southern states,—narrow defiles, where a few soldiers may dispute the passage of whole armies. Three of these notches are spoken of in New Hampshire, viz., the *White Mountain*,—sometimes called the *Crawford*, because of its proximity to the hotel of that name,—the *Franconia*, and the *Dixville*. The White Mountain Notch proper is only three miles long, nearly straight, running somewhat west of north. The northern end of it is shown in the heliotype opposite page 79, being the view from the Crawford house. A plain appears in front of the Gate of the Notch, formed by the transportation of decomposed granite down the sides of the steep hills. On the left is a bare rock called the "Elephant's Head," for obvious reasons. Behind rises the elevated mass of Mt. Webster, 2000 feet above the Gate, and 4000 feet above the sea. Future tourists


WHITE MOUNTAIN
NOTCH FROM MT. WILLARD


WILLEY HOUSE

will see a wider notch than that here represented, since it has been enlarged for the passage of the Portland & Ogdensburg Railroad. To the right is situated Mt. Willard, seemingly of little consequence; and still farther are the eastern slopes of Mts. Field and Tom.

If we rise a few hundred feet to the top of Mt. Willard, we shall get a glimpse of the entire lower part of the Notch. On referring to the small heliotype taken from this point, one can see the lower portion of the inclosing walls, the winding thread of the Saco river, and the granite mountains back of Frankenstein's cliff, after the turn of the valley to the south-east. The left-hand slope is on Mt. Webster, and the right is Mt. Willey. A few bare spots show where loose materials have slid down into the river; and we directly overlook the famous Willey slide. Mt. Willey is 3000 and Mt. Webster 2500 feet above the Willey house. The other part of this heliotype represents the house occupied by Mr. Willey in 1826, before the rushing down of the granite débris, in which he perished with his household. The larger house to the left has been added since 1826, for the accommodation of travellers. Only a small portion of Mt. Willey appears behind the house. Fig. 9 shows an outline of the slide, as it now appears, with the pile of stones erected in memory of the destroyed family.

A view of Mt. Willard from this point is of extreme beauty; and our heliotype,—one of the finest in the series,—is placed in the next volume for the sake of illustrating geological structure. The south side of Mt. Willard is precipitous, and it occupies the whole valley, the stream flowing down from the right of it. A cleft hollowed out of this precipice is known as the Eagle's nest or Devil's den. Marvellous stories have been told of it, as supernatural agents have been supposed to keep off all visitors. But our explorers of 1870, with the use of one hundred and twenty-five feet of rope let down from the summit, discovered nothing mysterious about this locality, but would not advise visitors to explore it again without better facilities for going and coming than they enjoyed.

Below the Willey house the valley turns south-easterly; and the heliotype opposite page 192, taken from this point, indicates the features of the mountains better than description. Mt. Willey terminates abruptly on the south, and the hills succeeding are 1500 feet less in height. Directly west from the Willey house are the remotest head waters of the Merri-

mack. Still farther to the south, the aspect of the Saco valley appears in the heliotype which shows Mt. Crawford, over Dr. Bemis's house, at Bemis station on the railroad. This is the last of the granite elevations on the east till Wilkes's ledge is reached, represented opposite page 220, in company with a view of Mt. Pleasant. The mountains on the west side are granitic throughout, the schists below Mt. Crawford constituting an island.

We are now prepared to understand the origin of the Notch. It has been excavated almost entirely out of granite. It lies near the eastern border of the vast sheet of Labrador granites heretofore described, perhaps on the line of eruption. This deep valley exists for the reason that the denuding agents have excavated it out of the softest materials occurring in this vicinity. The summits of Mts. Webster and Willey consist of flinty slates, which resist decomposition much more steadfastly than the intervening granite. A climb up both these mountains shows that the granite extends nearly to their summits. In descending, one finds an abundance of loose, friable rocks, inclined at the greatest angle possible for such materials. These fragments accumulate gradually through the action of frost, and, under favorable conditions, when rendered pasty by abundant rains, make a kind of plastic material which slides to the bottom of the valley, where the river disintegrates it still further, and carries it towards Conway. The plains below Bartlett are largely composed of the fragments brought down from this narrow valley. The Saco valley below Mt. Webster is lower, because the walls are composed entirely of this softer rock, and have yielded readily to the forces of disintegration.

The excavation of the broad valley of the Ammonoosuc to the west of the Washington range, bounded northerly by Mt. Deception, and southerly by Mts. Pleasant, Clinton, and Willard, is to be explained in the same way, only the materials have gone down towards the Connecticut instead of the Saco. The harder ridge remains on the east.

Other Varieties of Rock Sculpture.

Of the other shapes fashioned by Nature, the isolated, conical schistose mountains are the most unusual. Such are Monadnock, Kearsarge, Ragged, and numerous smaller eminences rarely heard of, like Peaked mountain in Piermont. Their peculiarity consists in the rising up from

a plateau of older formations of schists entirely isolated from any other deposits of the same age, yet with highly inclined strata. These are, unlike the sugar-loaf mountain structures, composed of nearly horizontal strata, which have been rounded by erosion. These elevations, like the latter, are relics of a once widespread blanket of rock; but the fragments have been doubled up by plicating forces, and their former connection seems difficult to believe. Their present separation is not due to erosion alone. It is also likely that there have been some special uplifts of land in connection with each of these summits. In New Hampshire these mountains are likely to be confounded with those of granitic origin, like the Stratford peaks.

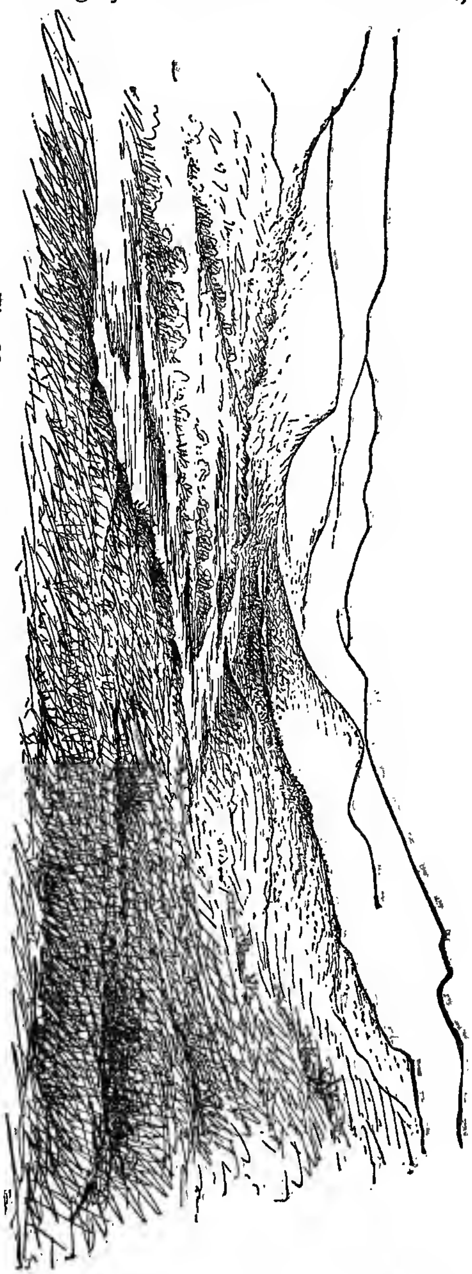


Fig. 88.—ANDROSCOGGIN VALLEY, FROM PEAKED HILL, GILEAD, ME.

I do not need to speak further of our ravines and gorges, as the most prominent ones have been described. Fig. 88 may illustrate some of our broad, sloping valleys, where level plateaus have been formed by the transportation of drift material. Our greater valleys of this sort are too extensive for representation. Such are the Conway plains, the barren expanse in Madison and Ossipee, and many other districts

in the south-east part of the state below the level of the 500-feet contour line. Where the work of transportation has been mainly effected by water, the sand is often left in one district, while the more fertile ingredients have been segregated from it, and deposited in alluvial meadows.

The Ascent of Mt. Carrigain. This mountain being practically unknown to tourists, I will reproduce, from our second annual report, a brief sketch of its ascent, by Prof. G. L. Vose. The results of another trip in 1874, by G. F. Morse, are given graphically in the atlas. The completion of the railroad through the Notch will now bring this mountain into notice.

Mt. Carrigain stands almost exactly in the centre of the vast group of the White and Franconia mountains, and, rising as it does to a height of nearly 5000 feet, is a marked feature in the landscape from almost every point of view. Conversely, the view from Carrigain must embrace the whole mountain mass, and must sweep around over all the principal summits.

The morning was bright and clear, and promised good weather for the ascent. Leaving our hotel directly after breakfast, we drove to Lawrence's farm, and, sending back our team, strapped our packs upon our backs, bid good-by to civilization and our paper collars, and took to the woods, following up the north bank of Sawyer's river. A walk of a little more than an hour brought us to Duck Pond stream, a tributary of the river from the north. Crossing this brook, we continued in a north-westerly direction for an hour and a half, when we struck Carrigain brook, the second tributary from the mouth of Sawyer's river. This brook has its rise both upon Mt. Carrigain and in the deep notch east of it, and thus leads by its west fork directly to the top of the mountain. Proceeding up the brook for an hour, we stopped at the foot of the ascent, which was now directly in front of us, to dine; and, after a short rest, commenced the climb, following the bed of the stream, which tumbles down the steep eastern slope of the mountain.

The summit of Carrigain is 4800 feet above the sea; the base of the mountain is probably about 1200 feet in height, thus leaving 3600 feet from the summit to the level of Carrigain brook, at least 3000 of which is in one almost unbroken slope, so steep as to require the constant use of both arms and legs in its ascent. The west fork of the brook leaps down for a great height over broad steps of granite; and this gigantic flight of stairs affords for a considerable distance the best means of ascent. The bed of this brook we named for our guide,—who was the first to ascend,—Cobb's Stairs. We kept the stream for about 1000 feet of vertical ascent, at which point it became so abrupt that we were forced to abandon it for the wooded slopes, where the foothold was better, and the trees offered us the assistance we needed for dragging up the constantly increasing weight of our bodies. The surface of the magnificent slope, up which

we were now toiling, appears to consist entirely of loose angular blocks of granite, dislodged by the frost, and covered with a deep matting of rich green moss, in which we sink to the ankles, and through which we not unfrequently break into some crevice up to the middle. For about two hours we work doggedly up this apparently interminable slope,—keeping the brook always in hearing, in order not to get beyond our supply of water for the night,—stumbling now into some hidden chamber beneath the moss, now lifting ourselves up by the friendly branches of spruce and pine, now sinking exhausted into the soft green bed beneath our feet, now winding around some fallen tree, still up, up, up we go, panting and straining, with every muscle called into play and every drop of blood in vigorous motion, till the distant mountains begin to lift their blue heads above the decreasing trees; till exhausted nature calls loudly for rest, and the small rill trickling beneath our feet is all that remains of our brook. * *

Daylight found us ready for the final pull, which should place us on the summit of Carrigain. Despatching our breakfast, and taking nothing but note-book and compass, we move slowly up, threading our way sometimes on foot, sometimes on our hands and knees, among the scrub spruces, and sometimes upon the rough, gray blocks of granite that strew the mountain side, till a shout from the guide sends new vigor into our muscles; and one more lusty pull, and a rough scramble through the bushes and over the rocks, and we stand upon a narrow ridge, from which the great slopes sweep down in one unbroken descent to the green carpet of forest spread out like a map beneath.

While we had been engaged in reaching this point, the clouds had not been idle. Indeed, they were a little ahead of us; and when we arrived upon the summit, we found the mountain mists creeping slowly in upon us, and one by one wiping out the great ranges that surrounded us. This was not pleasant; but we had come too far to give up the view from Mt. Carrigain, and, making a good fire, we sat down and awaited better times. Fortunately, they were not long coming; and, when we least expected it, a rift in the vapors showed the wide ring of the distant horizon, and the surging swell of the vast landscape around us.

Directly opposite to Mt. Carrigain upon the east rises a noble summit, scarred with tremendous slides, and forming with Carrigain a notch not inferior in depth or abruptness to the White Mountain Notch itself. [See view of Carrigain Notch, p. 596.] This fine summit we named Mt. Lowell, in honor of one of the oldest and most enthusiastic among White Mountain explorers,—Abner Lowell, Esq., of Portland. The slopes of these two mountains in Carrigain Notch are more imposing, both on account of their exceeding steepness and of their great height, than any others yet described in the White Mountains. The distant view, too, in every direction, is full of interest. Ranges and notches, huge mountains and broad valleys, never seen from the points commonly visited in this region, are spread all around. From its central position a better idea of the arrangement of the White and Franconia mountains is had than from any other point, perhaps, in the whole group. To the east we see Washington, Monroe, Franklin, Pleasant, Clinton, Jackson, Webster, Resolution, Giant's Stairs, Crawford, the Carter mountains, Doublehead, Pequawket, and the lower summits of

Jackson, Chatham, and Bartlett; to the south-east and south, the Mote, Chocorua, Tremont, Table mountain, Passaconnaway, Whiteface, Squam, and Tripyramid; while to the west and north-west lie the Franconia and Twin mountains, and the great mass of ridges and valleys between the Saco and the Pemigewasset. The view from Carrigain opens new fields in every direction for mountain exploration; and it is to be hoped that the many persons frequenting the mountains, and fond of rough tramps, will ere long penetrate these interior recesses of the wilderness, and acquaint us with the topography and geology of this now unknown part of the White Mountain group.

Cascades.

Cascades and waterfalls occur abundantly in New Hampshire, and they nearly always display the prevailing ledges of the vicinity, and consequently are sought for in geological explorations. I will mention only those which are figured, for their name is legion.

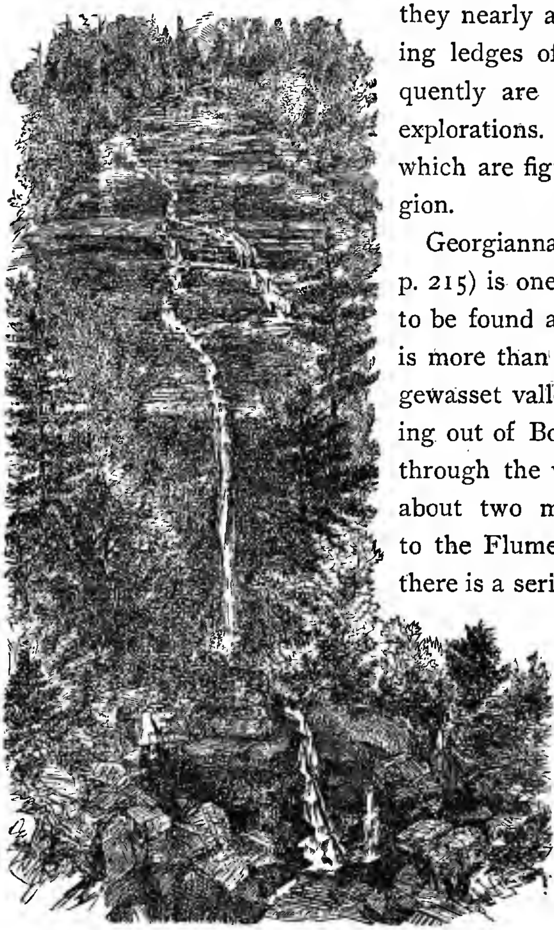


Fig. 89.—SILVER CASCADE.

Georgianna falls in Lincoln (Fig. 41, p. 215) is one of the grandest cascades to be found among the mountains. It is more than a mile west of the Pemigewasset valley, upon a tributary coming out of Bog pond. The path leads through the woods from a farm-house about two miles below the entrance to the Flume. For more than a mile there is a series of smaller cascades till the main fall is reached. This consists of two leaps of eighty feet each, which give the effect of a single fall, as seen through the trees from a distance. An extensive cut has been made in the rocks, which are largely of coarse granite veins:

Ripley's falls (Fig. 43, p. 226) are situated upon a brook near the Willey slide, and about two miles back from the Saco. The water leaps first over four stair-like ledges,—each about six feet high, which are not represented in the figure,—and then slides down a granite flume one hundred and fifty feet long, at an angle of forty-five degrees, ending in a large pool. The water is seventy-five feet wide at the base, and fifty at the summit. Still higher up the stream are two other falls, called the "Sparkling cascade" and the "Sylvan Glade cataract." There is a yet finer waterfall upon Bemis brook, about four miles farther down the Saco, upon the same side of the valley.

In the White Mountain Notch, rather more than a mile from the Crawford house, are the Flume and Silver cascades. The latter is figured best in the text adjoining, and the lower portion more particularly in a heliotype in Vol. II. It can be seen from the road, as it descends, for over three hundred feet. The fall is partly precipitous, but mostly at a comparatively small angle. The water flashes in the sunlight like silver: hence the name. In a very dry season it almost disappears from view.

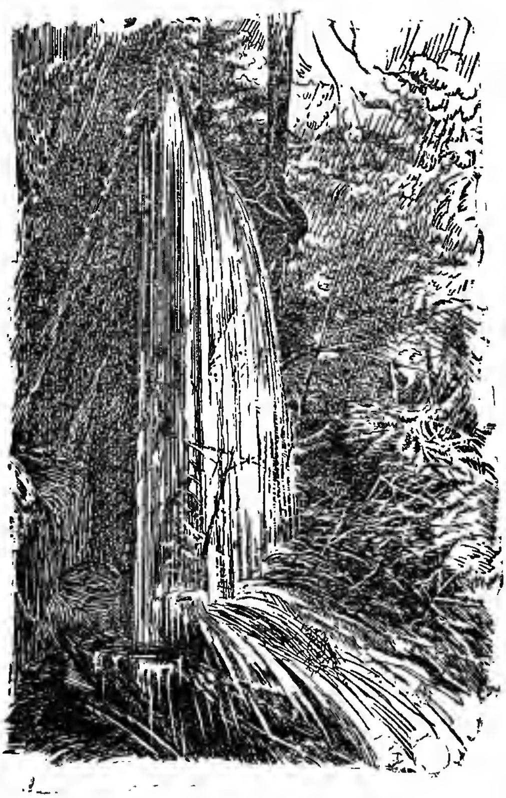


Fig. 90.—OUTLINE OF CUBA FALLS, ORFORD.

In Fig. 90 is an outline of Cuba falls, on the east side of Mt. Cuba in Orford. They were first brought to notice by the photographs of A. F. Clough, but are in a remote region rarely visited by tourists. It is unusual to see so great a fall of water leaving a clear space behind, as in this instance.

Opposite page 184 is a heliotype of the Crystal cascade. It is about

three miles south of the Glen house, near the height of land between Jackson and Gorham, and upon Ellis river. The water flows from Tuckerman's ravine. The view takes in about eighty feet of descent over slaty rocks crossed by igneous dikes. The view is taken from a high bank opposite the fall. The water is much spread out in this cascade, and, as the supply diminishes, is divided into several threads or frills.

The Glen Ellis falls are a mile farther south, and upon the same stream. These are a little higher than the one just mentioned. One is best impressed by their grandeur if he rests against a tree overhanging the precipice above the fall. The water is much more confined in its flow than at the Crystal cascade, and is more constant in its shape through both wet and dry seasons.

The view of the Jackson falls is placed opposite page 256. The rock here, and at the Goodrich falls lower down, represented in Vol. II, consists of slightly inclined sheets of granite. They are upon the Ellis river.

Opposite page 310 is a representation of Berlin falls in the Androscoggin river. As this stream is fed from the large lakes in north-western Maine, the supply is always large and constant. The descent is mostly a rapid rather than a cascade, amounting to nearly two hundred feet in the course of a mile. The gorge is nearly twenty feet deep, excavated through dark schists; and, by standing upon a bridge thrown across the river, one can best watch the mad descent of the river, from the smooth satin aspect to a "foam foliage, white and prismatic, cresting the leaping waves, and running from fall to fall." Early in the summer, logs are constantly passing through this narrow passage. These falls are close to the carriage-road, about six miles above Gorham.

Walker's falls, over granite sheets in Franconia, and Beecher's cascade, a little west of the Crawford house, are placed upon the same heliotype, opposite page 305. The joints are less easily recognized in the latter example. The Emerald pool, opposite page 232, is one of the resting-places for the active water in the midst of so much tumbling. It is just above Thompson's falls, and near the Glen house. In Diana's Bath, North Conway, opposite page 272, one sees a basin about ten feet deep, into which water passes from over a sheet of granite. It is near the "Cathedral."


GLEN ELLIS FALLS.

List of Illustrations of Scenery.

The following is a list of the illustrations, selected to set forth the scenery of New Hampshire, contained in this volume. The first are mainly printed from electrotypes of wood-cuts taken from Starr King's sketch of the *White Hills*. The others are the heliotypes, partly contained in this volume, and partly reserved for the next. The latter are more especially designed to illustrate geological phenomena.

List of Heliotypes Illustrating Scenery.

White-horse ledge, Conway, p. 592.

Dixville Notch, Chap. XIX.

Percy peaks, Stratford, from Stark, Chap. XIX.

White Mountain Notch, from the Crawford house, p. 79.

Carrigain Notch, from pencil sketch by G. F. Morse, p. 596.

White Mountains, from Berlin, from pencil sketch by G. F. Morse, p. 212.

Fac-simile of Gen. Field's sketch of the Franconia profile, p. 606.

Mt. Crawford, from near the Willey house, p. 192.

The following are placed in Vol. II:

Goodrich falls, Bartlett.

The Flume, Lincoln.

Mt. Pequawket, Chatham, from the Saco valley.

The Devil's Slide, Stark.

Mt. Chocorua.

Mt. Lyon, Northumberland.

The following are of smaller size:

Mt. Pleasant, from Twin River farm, p. 220.

Wilkes's ledge, Hart's Location, p. 220.

Mt. Crawford, from near Dr. Bemis's residence, Hart's Location, Vol. II.

Lake of the Clouds, Mt. Washington, Vol. II.

Mt. Willard, from the Willey house, Vol. II.

Silver cascade, Vol. II.

Eagle cliff, from Echo lake, Vol. II.

Eagle cliff, from site of former Lafayette house, Vol. II.

Walker's falls, Lincoln, p. 305.

Beecher's cascade, near the Crawford house, p. 305.

The Basin, Lincoln, Vol. II.

The boulder over the Flume, Lincoln, Vol. II.

Four winter views from Mt. Washington, p. 112.

Winter views of Carter range and Bourne monument, p. 104.

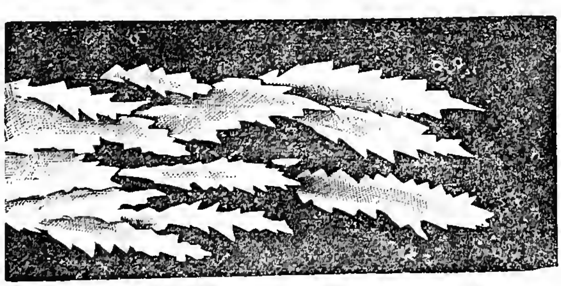


Fig. 91.—FROST FEATHERS.

CHAPTER XIX.

SCENERY OF COÖS COUNTY.

BY J. H. HUNTINGTON.

WHETHER we stand upon the summit of one of our highest mountains in winter, when there is embraced in the view the whole country from the ocean to the Adirondacks, or, in summer, we stand by the side of one of our quiet lakes, which is entirely encircled by lofty hills, while the blue dome of the sky seems to rest just on the hill-tops, there is a charm and enchantment in the scene that draws the mind away from things terrestrial, and bears it away into the realm of thought and fancy. From the mountain summits, the clouds that lie along the western horizon in such brilliant relief against a darker background become a celestial city, with towers and spandrels of gold; the lake and its immediate surroundings, shut out from all the world, become a paradise. The mountain summit in mid-winter, and the placid lake in summer, nestling among the hills, are the extremes. The first embraces all that is grand and sublime. The view is circumscribed only by the distant horizon; and the storms of mid-ocean pale before the blasts of the upper currents of the air. The outlook, with its ever-varying scene of clouds, and the storms sweeping along with such terrific grandeur, arouse the whole being. Instead of fear and terror, the mind grasps the whole as a grand and terrific display of the power that has fixed a limit even to these manifestations.

On the other hand, when in early summer there is a dreamy stillness in the air, and the foliage on tree and shrub has the freshness of spring, the placid lake, of all places else, soothes and brings a calm quiet to the mind; and, as a drowsy forgetfulness of things objective comes over us, and we are wafted away to indulge in such delicious reveries, then, when again we are conscious that this physical frame languishes unless it is nourished by something more substantial than dreams, we regret the condition of our physical existence, and almost wish that life itself were a dream.

To point out places of interest, where those who have a love for the grand and the beautiful can feast and be filled, rather than to describe the scenery, will be our object in the following pages.

If a person delights in primeval forests, he will certainly be charmed with the northern part of New Hampshire. A journey of a day and a half from Connecticut lake, through an unbroken forest, will take a person to Crown monument, which is at the extreme north-east corner of the state. It is on the water-shed between the waters of the St. Lawrence and the streams running south into the Atlantic, and it is so called because a monument was placed there by the commissioners who established the boundary between the states and the provinces. From a ridge of land 2568 feet above the level of the sea, where, looking northward, the land slopes towards the St. Lawrence, and southward, towards the Atlantic, the view must be extensive. In either direction we look over only illimitable forests, except that in the dim distance, a little to the east of north, there is a small settlement, probably at the north end of Megantic lake,—otherwise the view embraces a boundless forest. Immediately north, the slope is quite gradual, and, as it stretches northward, the country seems like a plain extending to the horizon. To the north-east is Saddle mountain, with hills and ridges; to the north-west, Megantic mountain rises as from an immense plain. Embraced in the view northward are the head waters of the St. Francis and Chaudiére rivers, while east and west is the high ridge that forms the water-shed. The view directly south is limited, for a mountain ridge runs from the Magalloway directly west into New Hampshire. To the south-west, the high ridge that encircles the basin where the many branches of the Magalloway have their source, obstructs the view in that direction. To the

south-east there is nothing, as far as the eye can see, but high ridges and mountain peaks, which follow each other in rapid succession until in the far distance they seem to pierce the sky.

If we should follow along the boundary between New Hampshire and Quebec province, there would be many points where we should wish to stop and view the grand panorama spread out before us. Two of the most remarkable outlooks we will notice. Not far from three and a half miles south-west from Crown monument there is a high point of land. If it was isolated from the ridge that extends in either direction from its summit, it would be a mountain of quite respectable proportions. Its height,—2812 feet,—would place it among the mountains. The distant view is not unlike that from Crown monument, but the immediate surroundings are much more grand; and chief among the attractions is a mountain lake, which lies in a depression to the west eight hundred feet below the summit, and it is so near that we seem to look directly down upon it. Another point of interest on the boundary is in the vicinity of Third lake. The view northward embraces a continuous forest, extending fifty miles or more; and in the distance, Megantic mountain stands massive and alone. One or two houses in Ditton are the only habitations that can be seen.

South, half a mile distant, we look down on Third lake. On a clear, bright day in early summer, when the stately forests are reflected in its waters, undisturbed by a single ripple, it presents a scene of quiet beauty that cannot be surpassed. Generally, the view southward is not extensive, but on some of the higher points we can overlook the nearer hills, and in the distance some of the peaks of the White Mountains can be seen.

Mt. Carmel.

Mt. Carmel rises 3711 feet above the level of the sea. It is on the line of New Hampshire and Maine, as the state line crosses it just as it begins to slope towards the west. The mountain consists of a long ridge, and, from the west, the ascent is quite gradual. On the ridge there are two points of nearly equal height, half or three quarters of a mile apart; from the point east there is a gradual slope for half a mile, and then the descent is almost perpendicular down to the débris formed from the fallen rocks. Before we reach this precipitous height, there is a ridge

that branches off and runs towards the north-east; and everywhere along the east side of this there are perpendicular walls of rock. As Mt. Carmel is somewhat isolated, the view from the summit is extensive.

Immediately northward is the great basin where rise the many streams that unite to form the Magalloway. Beyond is the ridge that forms the boundary between the states and the provinces, and through gaps in this we can see now and then a peak far to the north-east. To the east the view is very fine, while near at hand you look down into the valley of the Magalloway. Here you catch glimpses of the stream, and there you see one of the numerous lakes of this broad valley, for along this river there is scarcely a mile but that has its lake or bog. Save here and there, where the water reflects the bright sunlight, the whole valley is a dark forest of evergreen. Standing on the summit of Mt. Carmel in the afternoon, when the sun shines brightly, it is a grand scene to watch the shadows of the clouds as they fly across the valley,—they seem so etherial, yet so much like a thing of life. For displays of this kind, I know not any place where the effect is half so grand. Eastward, we can see far beyond the valley, and such an array of hills, ridges, and mountain peaks is rarely seen. Here is a mountain, irregular in outline and broken abruptly off; there are two similar in shape, while beyond and farther south is a mountain summit that has a graceful contour in its sweeping outline.

"And, glimmering through the sun-haze warm,
  Far as the eye could roam,
Dark billows of an earthquake storm
  Beflecked with clouds like foam,
Their vales in misty shadows deep,
  Their rugged peaks in shine,
I saw the mountain ranges sweep
  The horizon's eastern line."

Southward, we look down the Magalloway, and for twenty miles in a direct line the view is unobstructed; then, from the east, Mt. Agizcoös, with its bare summit, extends partly across the valley. Looking still southward in the far distance, sixty-five miles from the point where we stand, we see the White Mountains, in dim yet perfect outline. In some respects the view to the west and south-west is the most interesting. In

this direction there is a succession of undulating ridges and hills, which, with their shadows and ever-changing color, give a peculiar charm to the scene;—then, in the midst of the forests, those sheets of water that we can see are the Connecticut lakes. There is probably not another mountain peak in New Hampshire, so high as this, where one feels as though he was so entirely away from the habitations of men. In every direction, except a single spot at the outlet of Connecticut lake, which is fifteen or twenty miles distant by the shortest route, the whole country, embracing thousands of square miles, is one vast wilderness.

From the summit of Magalloway mountain, three miles east from Connecticut lake, there is a fine view of mountains, hills, and lakes. It is especially fine in autumn, after the forests of deciduous trees have put on their robes of beauty,—crimson, scarlet, and gold. The lakes which form such a marked feature in the scenery are noticed on page 223.

CASCADES.

Cascades are not very numerous in the northern part of Coös county, but there are two or three that deserve to be mentioned. On one of the western branches of Indian stream, near the north line of the Colebrook Academy grant, there is a cascade which, on account of its rare beauty, deserves especial notice. It is in a deep ravine, and on either side there is a dense forest of evergreens. Here the extreme heat of summer is unknown, for the cool breath from the water always tempers the atmosphere, and produces a delicious coolness that is so grateful in summer. The cascade has a height of forty feet;—the first twelve feet the water is broken by jutting rocks; for the remaining twenty-eight it flows over a ledge, which has a descent of sixty degrees. At the top the stream is four feet wide, but it spreads out so that at the base it is twenty feet. As the water runs across the strata, the effect is very fine. The pure water, the white spray, the dark, moss-covered rocks, the cool, delicious atmosphere, the shimmering light through the trees, the mossy banks of the stream, the perfect stillness save the music of the waters and the songs of birds, form a combination of attractions rarely found.

East from Connecticut lake, and south-east from the summit of Magalloway mountain, the Little Diamond falls in a series of rapid, wild cascades. The rapids extend for half a mile; and the fall in that distance


DIXVILLE NOTCH.

is one hundred and fifty feet. Besides the general rapids, there are perpendicular falls of from three to ten feet. South-west of the same mountain there is a fall on Huggins's Branch. For half a mile there are rapids, before we come to the falls; then there is a slope of fifty degrees and a fall of fifteen feet; then there is a fall twelve feet perpendicular; then there is a slope of forty-two degrees and a fall of about forty feet, confined between nearly perpendicular strata of rock, and water is thrown in spray against the wall; and finally it rests in a great basin at the base. A few rods below, the stream turns to the east, and has another fall of ten feet. Altogether, it is a beautiful cascade, and well worthy of a visit.

Dixville Notch.

Dixville Notch is regarded by many as one of the most remarkable exhibitions of natural scenery in the state, perhaps even surpassing the famous Notch of the White Mountains in picturesque grandeur. The angular and precipitous appearance of the rocks, rising hundreds of feet almost perpendicular on either side, is strikingly different from the rounded and water-worn appearance of most of the crystalline rocks throughout the northern part of the United States, and seems to come nearer to the scenery of the Alps than anything else in New England. This Notch is easy of access, being only ten miles from Colebrook village; and although the highest point in the road through the Notch is 830 feet above that village, yet the ascent is so gradual that few would believe they had reached so great an elevation. Approaching the Notch from the west, the road passes through a forest which in summer entirely obstructs the view, and the slow progress we are able to make causes now, for the first time in our journey, a sense of weariness. It is only for a very brief space, however, for scarcely have we time to complain before we reach an opening in the woods, and the grand view presented in the heliotype bursts suddenly upon us.

It surpasses most other notches in the vertical height of its walls, one point being 560 feet above the highest part of the road. Some of the highest precipitous masses stand out in bold relief from the sides. Table rock,—shown on the right in the heliotype,—projects 167 feet, while the ragged serrated edges everywhere form projecting points. One can easily imagine that he sees here the turrets and spires of some ruined

cathedral, or the battlements and towers of castles of the medieval age; or, as one stands on Table rock, he can imagine that a bridge once spanned the chasm below, and that these masses of rock standing in the débris are the ruins of piers on which it might have been built. The rock here differs in cleavage from that of similar composition elsewhere in New Hampshire. It splits in huge longitudinal fragments; and Nature has here quarried posts that equal in just proportion those wrought by human hands.

On Table rock the view embraces a wide sweep of country. We can see quite a distance into Maine, we can look over a part of Vermont, and it is said that, when clear, places in Quebec province can be recognized; and from Table rock the view down through the Notch is always grand. After passing the height of the Notch, going east on the right, we can see a profile,—"The Old Man of Dixville,"—which has very fair proportions. On the left, still farther east, there is an excellent representation of the walls and turrets of a ruined castle.

The "Flume" shows itself on the north side of the road, thirty or forty rods back in the forest. It is a chasm, in granite, about fifteen feet wide and fifteen rods long; and the stream running through it falls about thirty feet in cascades. In one place there is a pot-hole seven feet deep, with a diameter of four feet. The granite is divided by two vertical sets of seams or joints, so that large columnar blocks could be taken out without quarrying. The excavated rock seems to have been a trap dyke, part of which may still be seen. Nearly opposite the Flume, but farther down the valley, is Cascade brook, a branch of Clear stream. Upon this may be seen a series of cascades for more than half a mile. They were named Huntington cascades by the New Hampshire Press Association. The top of the most interesting cascade is 274 feet above its base. Here the stream is divided by a trap dyke two feet wide; and the water falls on each side a distance of forty feet. The rock here is the same argillaceous schist as in the Notch; besides, there is an interesting trap dyke, containing glassy feldspar and basaltic hornblende, which, Dr. Jackson says, resembles more a volcanic rock than any other found in the state. Most other notches we can see a long distance before we reach them, but here we have scarcely any intimation that there is such a vast rent in the mountain until we are almost in the very gap itself.

How was this Notch formed? is a question that is naturally asked, since it is so unlike all others. There is no theory so universally accepted as that there has been a time when the oscillations of the continent were considerable; that it was once submerged, so that at least quite a large part of New England was beneath the ocean; then, again, it was uplifted. That there have been two of these upliftings and depressions is quite certain.

The rock at Dixville Notch is very fragile, and there are reasons to believe that a fissure in the rocks here was originally produced by the uplifting of the whole rocky strata of the country, and that afterwards it was worn out by water and ice, perhaps a glacier. The principal reason for supposing a fissure, caused by uplifting, to have been the origin of the Notch, is, that in the rocks, several rods back from the edge of the Notch, there is now a fissure of unknown depth running parallel with the Notch, and consequently across the strike. It is well known that when great masses of rock are removed, the underlying strata contract and produce fissures. It is possible that this may have been the case at Dixville, since the mountain ridge is lower at the Notch than it is for several miles on either side. If at any point in the lowest part of the Notch we were able to find the strata standing vertically, as on the sides, we might suppose the Notch was originally produced by other causes. That ice did something after the fissure was formed, is evident from the fact that in the Notch and on the east side there are boulders that came from the west;—consequently they must have been carried into and through the Notch.

In Errol there is one of the grandest outlooks in New Hampshire, but, being off from any route of travel, it is scarcely known except to those who live in the vicinity, and to the fortunate few who have enjoyed the prospect. Here, we are not obliged to travel a long distance through the forests, neither have we to climb mountain summits, but on a travelled road we can sit in our carriage and overlook miles of forests, and in the distance see the grandest of our mountain summits. On the road from Errol Dam to Upton, Me., after crossing the Androscoggin, the road winds along and over the ridge of land between that river and Umbagog lake. As we ascend the hill, the grandeur of the scenery begins to unfold itself. On our right, and a little south of west, is the Andros-

coggin, which pours along over rapids until it rests in a quiet bay, where the river widens to receive the waters of Clear stream. After leaving the bay the river becomes rapid again, and pours along between the hills, and soon is lost to sight. Westward, among the hills, is Aker's pond, and, following up the valley of Clear stream, the view is limited by the high ridge running through Dixville. A little farther south we look over the hills in Errol and Millsfield, and we can see a few peaks in Odell. To the south-west the forests stretch as far as the eye can reach; for nearly thirty miles there is one unbroken wilderness. For a distant view, I know not where the White Mountains can be seen to such advantage as just south of the height of land; neither do I know of any distant point from which they appear so high. You seem to see through the Pinkham Notch, and in that direction, from most points, the higher peaks seem to slope off and run into the Carter range. Near Mr. William M. Thurston's, the White Mountains still in view, we can look down on Umbagog lake; and then in Maine, not many miles away, are mountains of considerable height.

On the Connecticut there are many places where the scenery is enchanting. At almost every turn in the road, from West Stewartstown to North Stratford, there is something that attracts the attention,—a mountain of grand proportions, a hill with graceful outline, the trees, the forests, or the river, as it runs through grassy meadows or along a wooded hillside. There is some remarkable scenery in the vicinity of Groveton. Coming from the south towards the village, Percy peaks will attract the attention of the most indifferent observer, on account both of their symmetrical form and color. In the heliotype, the peaks are seen from a point on the Upper Ammonoosuc above Groveton. In the foreground is the river, and to the right is Long mountain, near the line of Stark and Odell. The village itself is surrounded by mountains. The summits of those that are farthest away are scarcely more than ten miles distant, while Mt. Lyon on the south is not more than four. Although the hills and mountains are so near, yet, on account of the broad interval of the Connecticut, we do not feel as though the outlook had too narrow limits, but rather that in the whole view there is a beautiful symmetry. I know of no place where the moonlight adds such a charm to the scenery; and it is especially grand to watch the moon as it rises above

PERCY PEAKS.

the Pilot hills, breaks through the passing cloud, and throws its gentle light across the forests.

If we are not satisfied with the limit of the valley, there are hills on every side, climbing which we have distant views. From Percy peaks, northward, we have forests and wooded summits; south-east, the White Hills rise in all their grandeur; south, we have the long line of the Pilot hills; and, a little west of south, we look down the valley of the Connecticut, and in the distance Moosilauke rises against the sky. There are few mountains one feels so well repaid for the effort of climbing; and, besides the distant view, the peaks themselves are of interest on account of being so similar in outline, and so nearly of the same height.

The summit of the south peak is easily gained from the south-east, but the western slope of this, as well as the north peak, is so steep that it would require an expert in climbing to be able to reach the summit of either peak from that direction. There are few mountains where the variety of scenery is greater, for, besides the many mountain peaks, we have the Upper Ammonoosuc and the Connecticut winding along the valleys, their waters reflecting the bright sunlight, and ponds, too, surrounded by sombre forests, nestling among the hills. Stark is a town of mountains and hills, and there are several places where the scenery is indeed picturesque. Approaching Stark station, either from the east or west, the points of the mountains from the opposite sides of the valley project by each other so that there seems to be an impassable barrier across the valley; but we know that the stream must pass through the mountains, and Stark station is in the gap of the mountain through which it passes. On the north is a perpendicular wall of rock forming a vast amphitheatre, while on the opposite side of the valley, and a little east, is Mill mountain. Although in every other direction surrounded by high mountains, yet, looking a little west of south, we can see in the distance some of the high peaks of the Pilot range. At West Milan the peaks of the White Mountains begin to appear, and, besides, there is quite an array of mountains westward. There are some points where the effect is very fine. It is, however, in the south-east part of Milan, near the line of Berlin, and perhaps a mile east of the Androscoggin, that we have one of the most striking views of the White Mountains.

In Lancaster the view is always grand. Mt. Lyon to the north, and thence eastward the broad sweep of the Pilot range, and the group of mountains of which Starr King is the culminating point, are so situated that every fine sunset gives to them that deep coloring which is the charm of our mountain scenery. Most of the peaks of the White Mountains can be seen from the village, but a ride of two miles east on the road to Jefferson, to a point between three hundred and four hundred feet above the Connecticut, brings them out in bolder relief, and at the same time gives a charming view of the village and the Connecticut valley. From Mt. Pleasant, which is easy of access, the view is still more extended, and embraces the mountains southward. From Jefferson hill, and thence on the road toward Randolph, we get a nearer view of the mountains; and the appreciation of the scenery is shown by the demand for the numerous hotels in this vicinity. At the Mt. Adams house, the broad sweep of forests, reaching from Israel's river almost to the summits of the mountains, gives us one of the grandest of our autumn scenes. From Dalton mountain we have the sweep of the whole horizon: westward, the mountains in Vermont; the Connecticut valley northward; the mountains of Stratford, Mt. Lyon, the Pilot range, Starr King, all the White Mountains, the chief of the Franconia Mountains, and Moosilauke southward.

Albany Scenery.—Carroll County.

Albany, except one broad interval in the western part, is a succession of high ridges and mountain peaks. Here is Chocorua, with its serrated mountain ridge and granitic summit. Of all our mountains, there is none the summit of which appears so colossal as this, when seen from the south-east spur. As its forests have been destroyed, standing on this spur, it seems to be one massive granitic pile rising almost perpendicular from the ridge. But the mountain itself is grand, look at it from what direction we may,—from Lake Winnipiseogee, Eaton, or Conway, from Mt. Washington, or the mountains west. Even if we look down upon it as we pass over this mountain region in a balloon,—which we have had an opportunity of doing,—on account of its sharpness it seems more prominent than many mountains of greater height. But Passaconnaway is the highest mountain in Albany, and, rising as it does nearly

3000 feet above the interval of Swift river, and having deep ravines on the east and west, from the north it seems to stand up massive and alone. From the interval looking towards the north and north-west, we have a grand view of the mountains; but, ascending any of the small elevations south of the interval, the area of vision is increased ten-fold. Towards Mt. Carrigain the view is almost unobstructed, and there are many gentle undulations, with here and there a granite cliff standing out in bold relief, besides magnificent forests sweeping away up to the summits of the mountains; for none of the mountains to the west have been denuded of trees. In full view, Mt. Carrigain stands in all its massive grandeur, while north and south there are sharp peaks and mountain ridges. Still to the north, and yet not so far distant but that each peak and mountain ridge stands in sharp outline, the White Mountains rise in successive culminations, until Mt. Washington,—monarch of the range,—seems to touch the sky. While the immediate surroundings and the distant views are among the most attractive in the whole mountain region, there are two falls not far from the interval, one of which is of exquisite beauty. One of the falls is on Sabba Day brook, just in the edge of Waterville. The rock is a common granite, in which there is a trap dyke, and it is the disintegration of this, probably, that formed the chasm below where the steep fall now is. Above, just before we come to the falls, the stream turns to the west, and the water runs through a channel worn in the solid rock, and then, in one leap of twenty-five feet, it clears the perpendicular wall of rock, and falls into the basin below almost on the opposite side of the chasm. Great is the commotion produced by the direct fall of so great a body of water, and out of the basin, almost at right angles with the fall, it goes in whirls and eddies. The chasm extends perhaps a hundred feet below where the water first strikes. Its width is from ten to fifteen feet, and the height of the wall is from fifty to sixty. The water has worn out the granite on either side of the trap, so that, as the clear, limpid stream flows through the chasm, the entire breadth of the dyke is seen. The fall of water, the whirls and eddies of the basin, the flow of the limpid stream over the dark band of trap set in the bright, polished granite, the high, overhanging wall of rock, all combine to form a picture of beauty, which, once fixed in the mind, is a joy forever. The other falls referred to are known as Champ-

ney falls. There are two streams and two falls, but they are so near that they are known only as Champney falls. The stream on which they are found is the second stream that flows into Swift river from the south below Allen's saw-mill, and they are a mile and three quarters from the road. Following a logging-road that leaves the wagon-road at the first bridge below the mill, we cross the stream on which the falls are situated just above where they begin. A person who goes without a guide, and follows down the stream, will be at first disappointed, for all that is seen is a small stream, with a few massive blocks of a granitoid rock. It is true that even here there are immense caverns, and here the stream runs between two blocks, and then over another, when it falls on the great sloping ledge, and goes bounding along until it tumbles over a precipitous ledge, and is lost to view. We see where the water takes its last leap, yet nowhere does there seem to be anything very remarkable. But a person ought to see all there is to be seen before judging. We climb along the ledges, and, by following a rough path, get to the base of the falls,—yet there is nothing striking, nothing to see, certainly, that could tempt a person to travel nearly two miles through the woods alone. We are about to turn away sadly disappointed, when the eye catches a sunbeam reflected from the water, that seems to be struggling through the leafy foliage. Then, just there, not a dozen rods away, but almost hidden by the trees, we discover one of the most beautiful falls in New Hampshire. We stand just at the foot of the fall, on the stream we followed down. The sunbeams fall aslant through the trees; the eye follows the high perpendicular ledge that runs at right angles to the stream, and through the leaves of the trees we can see a small stream where it comes over the ledge, then falls down, striking the rock that projects just enough to throw the water in spray, and break, for an instant only, the continuity of the stream. In the entire fall there are three of these projections, where the water is thrown in spray, and, after the last continuous fall, it rests in a quiet basin, where it flows out and runs into the stream we had followed down. The entire fall may be sixty feet; and opposite, thirty feet distant, there is a ledge as high as that from which the water falls, so that probably where this gorge now is there was once an immense trap dyke, that has been disintegrated and carried away, and now we have the beautiful falls.

APPENDIX.

APPENDIX.

Additions to the List of Plants. Since the publication of the catalogue in Chapter XIII, several friends have added somewhat to the list. The following are all from Manchester, unless otherwise specified, and they were recognized there more than twenty years since, before the original growth had been removed to make way for manufactories, houses, and streets. One of the most interesting is the *Cupressus thyoides*, as it is a plant growing usually farther south. It illustrates the theory enunciated upon page 543, occurring in Manchester in connection with the *Rhododendron.* Italics denote naturalized plants, as before.

Papaver Rhœas.
Hanover.

Cerastium vulgatum.

Vitis cordifolia;
var. *riparia.*

Collutea arborescens.

Vicia tetrasperma.

Poterium Canadense. Burnet.

Pyrus arbutifolia.
var. *melanocarpa.*

Lythrum Hyssopifolia.
Hampton.

Mitella nuda.
Hanover.

Zizia integerrima.

Eupatorium pubescens.

E. teucrifolia.

Sericocarpus solidagineus.

Aster carneus.

A. Novæ-Angliæ.

A. tenuifolius.

Solidago patula.

Bidens bipinnata.

Ambrosia trifida.

Artemisia vulgaris.

Cynthia Virginica.

Anthemis arvensis. Chamomile.

Onopordon acanthium. Scotch thistle.

Leucothoë racemosa.

Pterospora Andromedea. Pine drops.
Hanover.

Utricularia resupinata.

Aphyllon uniflorum. Cancer root.

Veronica peregrina.

Gerardia purpurea.

Galeopsis Lodanum.

Bartonia tenella.

Apocynum cannabinum;
var. *hypericifolium.*

Amarantus hypochondriacus.

A. spinosus.

Rumex salicifolius.

Quercus bicolor. Swamp White oak.

Q. Prinus;
var. humilis. A Chinquapin oak.

Salix tristis.

S. nigra;
var. falcata.

Cupressus thyoides. White cedar.
Manchester and Newton.

Lemna polyrrhiza.

Iris Virginica.

Juncus militaris.

Eleocharis pygmæa.

Rhynchospora capillacea.

Scirpus polyphyllus.

S. lineatus.

Spartina cynosuroides.

Carex siccata.

C. Emmonsii.

C. Kneiskernii.

C. polymorpha.

Bromus Kalmii.

Panicum pauciflorum.

Equisetum variegatum.
Hanover.

E. scirpoides.
Hanover.

As some have thought the list of lichens, on pp. 413 and 414, was intended to comprehend everything of that class of plants, I will take occasion to say that it is intended to embrace only those which are peculiar to the White Mountains, but not those which grow there, and elsewhere, also. The list was compiled from Prof. Tuckerman's two valuable books, bearing the dates of 1872 and 1848. It is hoped that, by calling attention to the plants peculiar to the mountains, botanists may be induced to investigate further the question of the limits between the alpine and sub-alpine districts.

River Systems. Mr. Upham desires to correct the opening statement of Chapter XI, that one sixth part of New Hampshire is covered by water. The estimate was borrowed without reflection from the report of the New Hampshire Hydrographic Commission in 1870. He thinks the figure should be not more than one eighteenth, instead of one sixth.

Note to page 247. I understand that the boundary between Carlisle's and the Academy grants has been run out the present season, in accordance with the original line of forty-five degrees of north latitude.

Average Elevation. The average elevation of the land above the ocean should have been stated at twelve instead of fourteen hundred feet, on page 296.

INDEX TO VOLUME I.

ERRATA.

On page 49, line 15, for "April," read *May*.
On page 122, second line from the bottom, for "30°," read 50°.
On page 168, line 29, for "sin *l*," read *cos l*.
On page 151, lines 6 and 24, for "p. 6," read *p*. 150.
On page 92, line 18, for "Hornett," read *Thornette*.
On page 221, line 14, for "ascending," read *according*.
On page 273, line 13, for "Boscawen," read *Webster*.
On page 332, line 7 from the bottom, for "Gibbon," read *Gliddon*.
On page 379, last line, for "gennanica," read *germanica*.
On page 412, omit "B. lanceolatum," seventh line from the bottom.
On page 461, fourth line from the bottom, for "Samarancy," read *Samarang*.
On page 505, fifth line, for "Microsterias," read *Micrasterias*.
On page 541, line 9, for "Mt. Washington," read *White Mountains*.
On page 414, line 11 from the bottom, erase "P. oculata."
On page 212, line 2, omit "Mt.," before Wilton.